



# ***IEP NEWSLETTER***

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# OF INTEREST TO MANAGERS

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Even a casual read of this issue of the IEP Newsletter reveals an obvious, if unintended, theme—Doing Things Better. One could easily construct a Newsletter issue, purposely or inadvertently, around another theme—Doing Better Things. After all, the CALFED phenomenon has ushered in an era of many new initiatives in San Francisco Estuary monitoring, research, and management. But, Doing Things Better is also important. Not everything that is important is new, and important ongoing programs should evolve to take advantage of new technology and what has been learned from past efforts. Those reporting in this issue provide ample evidence that many important, ongoing things are being done better.

Marade Bryant, in her update on the results of the 2003 Summer Towntnet Survey describes an important change in this venerable early summer survey of juvenile fish abundance and distribution in the upper estuary. The survey, which was initiated in 1959, was originally designed to establish the strength of the new striped cohort at the time the cohort averages 38 mm in length. Fortunately, the designers and early implementers of the survey had the interest and foresight to identify and measure all fish captured, providing us all with a 44-year record of juvenile fish occurrence as the fish community has responded to the many natural and man-induced changes in the estuary. These folks with their slow boats and small budgets still had to be very focused, so the survey was intentionally designed to begin in response to striped bass spawning conditions and last only until the abundance at 38 mm had been established, which resulted in variable numbers and timing of surveys each year. This intended variability has to some extent inhibited our ability to accurately track year to year variation in the juvenile abundance for other species, particularly delta smelt. So, beginning in 2003 the Survey will begin on essentially the same date each year and include a standard (6) number of individual surveys. This initiates a new era of greater utility of Survey results, without orphaning the information gathered since 1959.

The US Fish and Wildlife Service in Stockton has added a robust species identification quality control component to their Delta Juvenile Fish Monitoring Program, Lia McLaughlin reports. Given the disturbing frequency of invasive fish and macroinvertebrate introductions and the difficulty in field identification of similar-looking, but ecologically dissimilar species ensuring consistent and proper identification of species encountered is critical to producing meaningful monitoring results.

Russ Gartz updates us on the IEP's effort to examine the feasibility of deriving biomass and condition indices from some of our major fisheries monitoring programs. Presently, most of our surveys report only indices of species abundance. Additional insights about system productivity and community structure could be obtained if biomass indices were available.

A prodigious article by Kitty Triboli, Anke Mueller, and Marc Vayssières of DWR addresses the very important topic of maintaining method continuity and data comparability as long-term monitoring programs evolve to take advantage of improved methods. The article focuses on the comparison of methods used before and after 1998 by IEP's Environmental Monitoring Program to measure chlorophyll concentrations. The authors conclude that a data correction in response to the methods change is not warranted, but, more importantly, provide other IEP investigators a detailed analytical road map for evaluating the data implications of changing methods during a long-term monitoring program.

Continuing the "Doing Things Better" theme, articles by Doug Demko and Lauren Buffaloe report, respectively, on an improved method of enumerating adult salmonids ascending Central Valley streams and a new on-line journal to facilitate the peer-reviewed reporting of scientific information relevant to the management and protection of the estuary. It is often the case that very good Bay/Delta/Central Valley scientific articles are denied publication in national journals because they are "too local". Peer-reviewed outlets such as CALFED's new on-line journal and DFG's Fish and Game Quarterly allow for more reliable publication of good quality local scientific results. This is particularly important, given the phenomenal recent expansion in San Francisco Estuary and tributary scientific investigation.

# IEP QUARTERLY HIGHLIGHTS

## July-September 2003

### Summer Townet Survey

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The 2003 Summer Townet Survey (TNS) completed six surveys, the most in its 44-year sampling history. This season was the first year a predetermined number of surveys was completed, with a start date in the first or second week of June. Historically the TNS started in late June or early July and continued sampling until the average size of striped bass reached 38.1 mm, sometimes only necessitating two surveys. The adoption of a standardized six-survey schedule should provide more consistent recruitment information for other species, such as delta smelt, threadfin shad, American shad, and longfin smelt. The extended effort should also provide better late recruitment information on striped bass in cool, wet years.

The 2003 TNS generally captured fewer fish than 2002, despite the fact fewer surveys (4 vs. 6) were conducted in 2002. Threadfin shad largely accounted for the decrease, with the 2003 catch being only 9% of the 2002 catch. The number of striped bass, American shad, and splittail caught in the TNS increased from last year beyond what would be expected from the two additional surveys, while the number of delta smelt, longfin smelt, and threadfin shad caught in the TNS decreased (Table 1).

**Table 1 Townet Survey total catch by species for 2002 (4 sub-surveys) and 2003 (6 sub-surveys)**

<i>Species</i>	<i>2002</i>	<i>2003</i>
Striped bass	307	1773
Longfin smelt	442	90
Delta smelt	464	338
American shad	5	361
Threadfin shad	8385	767
White catfish	195	712
Channel catfish	93	335
Yellowfin goby	18	79
Arrow goby	0	1
Shimofuri goby	59	12
Shokihaze goby	166	64
Tridentiger spp.	400	50
Northern anchovy	60	64
Pacific herring	6	5
Starry flounder	3	8
Three spine stickleback	12	26
Goldfish	0	2
Splittail	2	29
Inland silverside	23	123
Tule perch	0	1
Plainfin midshipman	8	4
Rainwater killifish	2	10
Pacific lamprey	1	0
Prickly sculpin	1	0
Chinook salmon	0	3
Topsmelt	9	2
Jacksmelt	1	0
Total	10,662	4,859

### Mysids and Zooplankton

*W. Lee Mecum (DFG), lmecum@delta.dfg.ca.gov*

Monthly lower estuary zooplankton sampling in South San Francisco Bay, Central San Francisco Bay, and San Pablo Bay began in July. This lower estuary zooplankton sampling is a pilot program (funded only for 2003) designed to test the feasibility of extending Inter-agency Ecological Program zooplankton monitoring into these lower embayments and to test the efficacy of potential sampling gear improvements. Two pairs of stations are being sampled in each bay; each pair consists of a

channel station and a nearby shoal station. At each station a 0.5-m diameter 500-micron mesh macro-zooplankton net, a 12.5-cm diameter 154-micron mesh meso-zooplankton net, and a pump are deployed

The lower estuary pump sample size is approximately 42 liters as opposed to approximately 1.8 liters for the upper estuary samples, which should increase the probability of capturing species present in low numbers. Two different pumps are being used at the shoal stations to determine whether a more powerful pump will capture micro-zooplankton at densities that are similar to the historic upper estuary micro-zooplankton pump. Because the larger pump samples take more specimens, they require much more time to process than the historic 1.8 liter samples. Sample processing has been temporarily suspended due to staffing shortages. A lab study will be conducted to develop a subsampling procedure that will retain the resolution provided by the increased sample volume and reduce processing time to an acceptable level.

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## San Francisco Bay Fisheries Monitoring January-September 2003

*Kathy Hieb, Tom Greiner, and Steve Slater (DFG),  
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Summer and fall catches of several cold-temperate species, including Dungeness crab, English sole, and starry flounder, increased or remained level in 2003. The increases occurred in spite of slightly warmer ocean temperatures during the reproductive period; the mean sea surface temperature in the Gulf of the Farallones was 1-1.5 °C warmer in winter 2002-2003 than the previous 3 winters. However, it was 1.5-2 °C cooler than in winter 1997-1998, which was the last strong El Niño event.

The 2003 Dungeness crab age-0 index will be the third highest for the period of record (1980-2003) and follows the fourth and second highest indices in 2002 and 2001, respectively. Although our May-September catch of age-0 starry flounder was the highest since 1997, the 144 age-0 fish collected this year is low relative to our catches from the early 1980s. English sole age-0 catch was again high in 2003, with a total catch of about 4,000 fish from February to September. This is almost

identical to the 2000 and 2002 catches and will result in 4 consecutive years of high abundance indices.

In contrast, the 2003 Pacific herring age-0 catch declined after 3 years of increasing catches. The 2003 age-0 catch was about half the 2002 catch, with approximately 3,600 fish from April to September. Although the 2003 index will probably be slightly lower than the average index for 1980-2002, it will be higher than any of the 1990-1999 indices. The adult Pacific herring biomass estimate for San Francisco Bay, based on spawning and hydroacoustic surveys, was again low in 2002-2003, with few older fish in the population (D. Watters, DFG, pers. comm.). Our low age-0 Pacific herring indices through the 1990s and increased indices since 2000 support this conclusion.

Several warm-subtropical species have been common in our catches this year, but not all are reproducing here. In 2003 we continued to collect age-0 and older Pacific sardine. We first collected Pacific sardine consistently in the early 1990s, with the highest catches in 1997-1999. There is now a large Central California population of sardines and some of these fish enter the Bay in mixed schools with northern anchovy and Pacific herring. We also collected multiple age classes of California grunion, including age-0 fish, in 2003. We first collected California grunion in 2001 and have collected increasing numbers each year. Older, legal-size California halibut are still common in the Bay, but we have not collected age-0 fish since 1999. This is consistent with our hypothesis that there is no local reproduction of California halibut until coastal temperatures reach 14 °C for several months.

Our catch of many of the surfperches has increased this year. This includes the more common walleye surfperch and pile perch, as well as the less common barred surfperch, white seaperch, dwarf perch, and rubberlip seaperch. We will report on the status of all the surfperches, including the less common species, in the 2003 Status and Trends issue of the IEP Newsletter, to be published in spring 2004.

This year we have caught a wide array of unusual native fish, including 3 species collected for the first time and 4 collected for only the second time in 23 years. The 3 species new to our study are the bocaccio (*Sebastes paucispinis*), a tentatively identified mussel blenny (*Hypsoblennius jenkinsi*), and thornback (*Platyrrhinoidis triseriata*). All 3 fish were collected in Central San Fran-

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cisco Bay. In 2003, we collected our second eulachon (*Thaleichthys pacificus*), second redbelt surfperch (*Amphistichus rhodotus*), second shovelnose guitarfish (*Rhinobatos productus*), and second slipskin snailfish (*Liperus fucensis*).

We have also seen noteworthy increases in the catch of a few formerly rare species. We collected our first buffalo sculpin (*Enophrys bison*) in 1997, and our second in 2001; through September of this year we collected 26. Thus far this year we have collected 162 saddleback gunnels (*Pholis ornate*); we collected 60 in 2002, 11 in 2001, and only 10 from 1980 to 2000.

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## Delta Juvenile Fish Monitoring Program

Lia McLaughlin (USFWS), [lia\\_mclaughlin@fws.gov](mailto:lia_mclaughlin@fws.gov)

The Interagency Ecological Program (IEP), through the Delta Juvenile Fish Monitoring Program, has monitored the relative abundance of juvenile fall Chinook salmon (*Oncorhynchus tshawytscha*) in the Sacramento-San Joaquin River system since the mid-1970s. A year-round monitoring program was implemented in fall 1991 to monitor juvenile Chinook salmon of all races as well as resident fishes. Sampling for the summer quarter (July through September 2003) was similar to previous years. Trawling was conducted on the lower Sacramento River at Sherwood Harbor, the San Joaquin River at Mossdale, and Chipps Island. Shallow-water seining was conducted in the lower Sacramento River, the San Joaquin River, the Delta, and the San Francisco Bay.

More than 77,000 fish were captured during sampling this quarter, divided among 50 species. Catches were dominated by American shad (*Alosa sapidissima*; n=21,117), threadfin shad (*Dorosoma petenense*; n=13,686), and silversides (*Menidia* spp.; n=32,509). Over 97% of the American shad were collected during trawling at Chipps Island, primarily during August and September. In contrast, less than 1% of the threadfin shad was captured at Chipps Island. The remaining threadfin shad were divided between the Sacramento River (54%), San Joaquin River (33%), and Delta (12%). In the Sacramento River, most of the threadfin shad were captured in July; while in the Delta, most were captured in September. In the San Joaquin River, threadfin shad were captured

throughout the sampling quarter. Most of the silversides were captured during seining in the Delta (58%) and San Joaquin River (37%). Delta catches of silversides peaked in August, while catches of silversides in the San Joaquin River peaked in September.

As in previous years, few Chinook salmon were recovered during this time. In total, 37 Chinook salmon were captured. Twenty-nine Chinook salmon were captured at Chipps Island: 20 fall sized (76 to 105 mm), 6 adults (over 500 mm), 2 late-fall sized (87 and 100 mm), and 1 spring sized (239 mm). Five were captured at Sherwood Harbor, all fall sized (69 to 97 mm). Three were captured during seining in the Sacramento River and North Delta, all fall sized (73 to 81 mm). Less than 400 Sacramento splittail (*Pogonichthys macrolepidotus*) were recovered: 246 were captured during Delta seining, 51 were captured in Chipps Island trawling, 34 were captured in the Sacramento River (seining and trawling combined), and 58 were captured in the San Joaquin River (seining and trawling combined). Eighty-four Delta smelt (*Hypomesus transpacificus*) were identified. Most (93%) were captured during trawling at Chipps Island, and most of these were captured in July and August. No steelhead trout (*O. mykiss*) were recovered during sampling this quarter.

In addition to the fish species identified, 344 Siberian prawns (*Exopalaemon modestus*) and 4,452 jelly fish (*Maeotias marginata*) were identified. Most of the Siberian prawns were captured in August during seining in the Sacramento River and August and September trawling at Chipps Island. All *M. marginata* were captured in Chipps Island trawls, primarily in September.

Last year we hired a full-time quality control biologist and implemented a quality control program, to assess and improve the accuracy of our fish identification. Currently, 15% of our total catch is verified for accurate fish identification. Overall, our error rate is less than 1%, with most errors occurring during identification of juvenile sunfishes and minnows (Hansen, personal communication, see Notes). Our quality control program is evolving to address new fish identification issues as they arise. During this quarter, we identified some discrepancies in our fish identification. With assistance from California Department of Fish and Game staff, personnel from the US Bureau of Reclamation (Tracy Fish Facility), an advanced fish identification course offered at University of Califor-

nia, Davis, and refresher training, we are improving our ability to accurately and efficiently identify juvenile fish.

## Notes

Hansen, Larry. 2003. US Fish and Wildlife Service, Stockton Fish and Wildlife Office. In person communication with L. McLaughlin. October 3, 2003.

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## Decker Island Fish Monitoring

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The Decker Island Habitat Enhancement Project is in Solano County, on Decker Island. Approximately 15 acres of wetland and riparian habitat was created on Department of Fish and Game (DFG) property through the Department of Water Resources' (DWR) Delta Levees Program. As a condition of the permits, a fish monitoring program was developed to assess the affects of this newly created habitat. This is a five-year program to monitor the fish community inside, as well as outside, the restoration site. This is the first year for implementing the monitoring program.

Fish monitoring began in spring 2003. Monthly seine samples were collected from March through July in two to three channels inside the restoration site. Due to the channel depths, the channels could only be effectively sampled on a negative tide. This had the benefit of forcing most of the fish from the tules into the channels. The channels were blocked with a net, and a seine was then swept from the block net to the end of the channel three times. After the third seine haul, the block net was picked up and swept to the end of the channel. For reference sites, beach seines were conducted near the opening of and downstream from the restoration site. The channels and reference sites were also electrofished once in March.

The block net-beach seine sampling in the restoration channels worked well for the nonbenthic fishes. By the end of the second seine haul, we caught, on average, 87% of the fish present as estimated by the catch depletion method. On the final haul, approximately 100% of estimated fish present were caught. In contrast, very few benthic fish were caught using this method. The low catch of benthic fishes was probably due to fish swimming under the nets, because even on the low tide the nets did

not always reach to the bottom of the channel. In contrast, electrofishing wasn't as efficient as seining and fewer fish were caught in similar habitats sampled. However, we were able to electrofish areas where we couldn't seine. Electrofishing was selective for larger fish as compared to seining.

Inside the restoration site, 20 species of fish (6 were native) were caught with the seine and 11 species (3 were native) were caught electrofishing. In the reference sites, the seine caught 18 species (7 were native) and electrofishing caught 10 species (4 were native). The most common species for each type of sampling gear are listed in Table 1. Of the fish caught with the seine in the restoration site, 13% were native. Approximately 33% of the fish were native at the reference site. In contrast, the one electrofishing event indicated a slightly higher proportion of native fishes at the restoration site than at the reference sites, 41% to 30% respectively. Overall, native fishes were more abundant from March through May. Very few native fishes were caught in June and July.

We plan on continuing the block net-beach seining and electrofishing efforts; future sampling may also target larval fishes. Although not reflected in the catch (Table 1), thousands of small (<25 mm) centrarchids and cyprinids were caught in June. It appears the restoration site provided substantial spawning and rearing habitat for non-native fishes. Traps and gillnets may also be used to catch the benthic fishes which were missing in the seining and electrofishing efforts. With California Bay Delta Authority (CBDA) involvement in DWR's Phase II of Decker Island (the creation of more habitat by extending the length and reach of one of the channels), more directed research fish studies will be developed in the upcoming years. Results from this monitoring and any CBDA research studies, as well as results from other restoration studies, will provide guidance for future native fishes habitat creation on Decker Island.

**Table 1 Percent abundance of the most common species caught, by sampling gear and location, at Decker Island in 2003**

		<i>Seine</i>		<i>E-fishing</i>	
	<i>Common Name</i>	<i>Restoration</i>	<i>Reference</i>	<i>Restoration</i>	<i>Reference</i>
Non-native	Inland silverside	27%	22%	11%	
	Bluegill	22%		9%	7%
	Golden shiner	12%	1%	19%	
	Largemouth bass	10%	1%	11%	20%
	Threadfin shad	3%	8%	2%	
	Yellowfin goby		33%		
	Common carp				30%
Native	Chinook salmon	4%	15%	9%	7%
	Sacramento pikeminnow	3%	9%	19%	3%
	Hitch	2%		13%	
	Tule perch	1%	2%		17%
Total Number of Fish		1,665	789	64	30

## Length-Weight Study Update

Russ Gartz (DFG), [rgartz@delta.dfg.ca.gov](mailto:rgartz@delta.dfg.ca.gov)

The main purpose of the IEP's Length-Weight Study (LWS) is to facilitate the development of fish biomass and condition indices from IEP's various San Francisco Estuary fish surveys. At present, our monitoring program fish indices are abundance indices derived from counts of fish captured during surveys. The availability of biomass and condition indices would enhance our understanding of the estuary's fish trends and the factors affecting trends. In addition to developing biomass and condition indices, the LWS is investigating the efficacy of determining length-weight relationships using digital imaging.

Specimen collection started in April 2003 and is expected to continue through February 2004. Specimens are collected from the San Francisco Bay Study, Summer Townet Survey, Fall Midwater Trawl Survey, and the US Fish and Wildlife Beach Seine Survey. Fish are returned to the Department of Fish and Game's Stockton lab for processing.

Laboratory processing consists of measuring the standard, total, and (in appropriate cases) fork length of each fish to the nearest millimeter and weight to the nearest

0.1 milligram. Fish exhibiting substantial physical damage from capture are excluded from the analysis. All fish were lightly patted dry to remove excess water before weighing.

The LWS has had to prioritize and temporarily reduce research objectives due to laboratory staff limitations resulting from the current state budget situation. Because our preservation method is isotonic salt solution (roughly 12 ppt) and refrigeration on ice, laboratory processing cannot be delayed for more than roughly 1 week. Unfortunately, the numbers of specimens required to address all 3 research objectives (biomass indices, condition indices, and digital imaging) cannot be processed within the 1-week limit. Therefore, all field and laboratory work is currently focused on completing the length-weight tasks needed for the biomass indices.

Length-weight relationships are calculated using non-linear regression techniques in SAS's PROC NLIN (SAS Institute, Inc. 1989). The formula used for the length-weight relationships for all species was (Anderson and Neumann 1996):

$$\text{WEIGHT (gm)} = a * \text{LENGTH (mm)}^b$$

Relationships are calculated using standard and total length for all species and fork length for applicable species.

Of the 16 species for which we hope to achieve biomass estimates (Table 1), specimen collection and development of length-weight relationships has been completed for two species, striped bass (*Morone saxatilis*) and bay goby (*Lepidogobius lepidus*). Specimens were collected in a relatively wide range of sizes (Table 2). Figures 1 and 2 display the length-weight relationships for striped bass and bay goby, respectively. Analyses of the length-weight relationships indicate that the fits for both species were very good. Variability increased with length for both species.

Table 1 Species selected for collection of length and weight data by DFG's LWS	
Common Name	Scientific Name
Speckled sand dab	<i>Citharichthys stigmaeus</i>
English sole	<i>Pleuronectes vetulus</i>
Plainfin midshipman	<i>Porichthys notatus</i>
Shiner surfperch	<i>Cymatogaster aggregata</i>
Northern anchovy	<i>Engraulis mordax</i>
Pacific herring	<i>Clupea pallasii</i>
American shad	<i>Alosa sapidissima</i>
Bay goby	<i>Lepidogobius lepidus</i>
Yellowfin goby	<i>Acanthogobius flavimanus</i>
Staghorn sculpin	<i>Leptocottus armatus</i>
Topsmelt	<i>Atherinops affinis</i>
Jacksmelt	<i>Atherinop californiensis</i>
Striped bass	<i>Morone saxatilis</i>
Threadfin shad	<i>Dorosoma petenense</i>
Longfin smelt	<i>Spirinchus thaleichthys</i>
Delta smelt	<i>Hypomesus transpacificus</i>

Table 2 Minimum (MIN) and maximum (MAX) measures for striped bass and bay goby from DFG's LWS. Sample size is indicated in parenthesis; weight is in grams and lengths are in millimeters.

	Striped Bass			Bay Goby		
	Min.	Max.		Min.	Max.	
Weight	0.0403	41.973	(288)	0.0699	6.4202	(214)
Standard length	14	131	(238)	22	78	(210)
Fork length	15	148	(288)	Not Applicable		
Total length	16	158	(238)	26	93	(214)

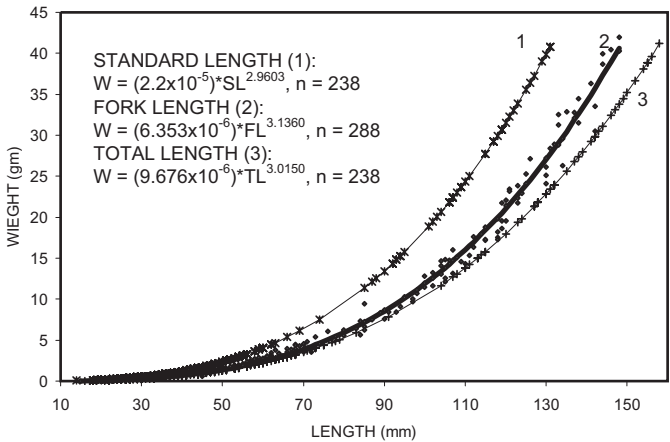


Figure 1 Length-weight relationships for striped bass from DFG's LWS. Data from the fork length-weight relationship is shown.

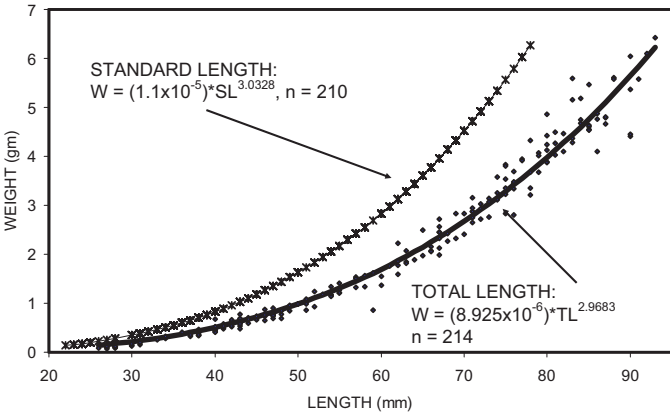


Figure 2 Length-weight relationships for bay goby from DFG's LWS. Data from the total length-weight relationship is shown.



There are 4 major potential sources of variability in the length-weight relationships: differences in growth rate, preservation technique (see above), processing error, and gonad development (gobies only). Specimen collection was designed to obtain a variety of fish sizes. We have not attempted to account for variation in growth rate due to fish age or capture location. Our method of preservation (see above) is intended to minimize the gain or loss of body water via osmosis. Variability due to preservation technique will be evaluated at a later date. Variation due to processing error will also eventually be evaluated. Grossman (1979) encountered ripe bay gobies (> 40 mm SL) from September through March, and Wang (1986) reported larval bay gobies from November through May; these studies indicate that bay gobies in the size range encountered (Table 2) potentially could have spawned during the time the LWS was collecting them. This potential variability due to gonad development was not accounted for by the LWS.

The LWS will continue to determine the length-weight relationships for the remaining 14 species to develop biomass indices, which is the program's top priority. An evaluation of those data already collected will be made in 2004 to determine if condition indices (objective 2) can be developed. One day of digital imaging (objective 3) has been conducted, but further work has been delayed indefinitely.

## References

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## Adult Striped Bass Population Study

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Management of striped bass in the estuary requires accurate, age-specific estimates of adult striped bass abundance, especially because their management must be consistent with protection of endangered fishes. Accurate adult estimates are also essential for developing a robust understanding of population dynamics and how these dynamics are influenced by environmental factors. Understanding striped bass responses to environmental change and variability provides important insights and hypotheses about the responses of other species for which less data is available. Using a slightly modified Petersen mark-recapture method, we estimate the population size of adult striped bass (stratified by age and sex)  $\geq 42$  cm fork-length in the estuary.

We typically capture striped bass in the San Joaquin and Sacramento rivers during their spring spawning migrations (on even-numbered years) using gill-nets deployed by boat and in fyke traps set along the Sacramento River. Crews document, remove several scales from, tag, and then immediately release each healthy fish. We also monitor fish captured and recaptured during the recreational harvest and subsequent-year tagging, and use that information to calculate abundance.

Staff attempt to determine the age of each captured fish by interpreting patterns of growth on scales. We can calculate abundance once all (or nearly all) observed fish are assigned an age. We update prior abundance estimates as substantial blocks of information (for example, from the creel and from tagging) become available.

From the mid-1960s through 1994, adult tagging and estimation was accomplished annually. Unfortunately, the adoption of alternate (even-numbered) year sampling after 1994 may have resulted in an unacceptable degradation in estimate precision. In addition, alternate year sampling proved much less useful in understanding population responses to environmental conditions.

In an effort to reduce the confidence intervals about the estimate(s) and improve data utility, we tagged striped bass during 2003. Staff captured striped bass in gill-nets deployed by boat and in fyke traps during late spring. The boat crew observed 2,025 striped bass, tagged

1,828 striped bass, and recaptured 31 tagged striped bass. The trap crew observed 2,556 striped bass, tagged 2,238 striped bass, and recaptured 20 tagged striped bass. Due to budgetary constraints and priorities, many fish captured in 2002 and 2003 have not been aged and (thus) updates of prior abundance estimates are not available. However, we are now rapidly estimating the age of those fish and anticipate reporting new abundance estimates in the next IEP newsletter.

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## Shallow Water Predator-Prey Dynamics Study

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Following pilot efforts in 2000, the Shallow Water Predator-Prey Dynamics Study evaluated patterns of habitat use, diet composition, and prey fish consumption by striped bass (*Morone saxatilis*), largemouth bass (*Micropterus salmoides*), and Sacramento pikeminnow (*Ptychocheilus grandis*) collected during March-October 2001 and 2003. We presented preliminary results for striped bass and largemouth bass earlier this year (Nobriga and others 2003).

To date, we have collected nearly 80,000 fish, including more than 7,000 individuals of the three target species. We expect to produce a full article for the winter 2004 issue of the IEP Newsletter that will report 2001 and 2003 fish and macrocrustacean catch statistics and describe our sampling gear efficiency. We plan to spend the rest of 2003 and most of 2004 finishing lab work and writing manuscripts for publication.

## References

Nobriga M, Chotkowski M, Baxter R. 2003. Baby steps toward a conceptual model of predation in the delta: preliminary results from the Shallow Water Habitat Predator-Prey Dynamics Study. IEP Newsletter 16(1): 19-27.

# NEWS FROM AROUND THE ESTUARY

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## Delta Regional Ecosystem Restoration Implementation Plan

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## Introduction

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) is the first of four regional plans for implementing the California Bay-Delta Program's (CBDP) Ecosystem Restoration Program (ERP) element. The DRERIP will articulate the scientific rationale and level of certainty associated with ERP actions described for the Delta, thereby establishing a more rigorous planning foundation. It will also refine existing Delta-specific restoration actions and provide Delta-specific implementation guidance, program tracking, performance evaluation, and adaptive management feedback.

Preparation of the DRERIP is a collaborative effort involving the following ERP Implementing Agencies: the Department of Fish and Game (DFG) (lead); National Oceanic and Atmospheric Administration (NOAA) Fisheries; the US Fish and Wildlife Service (USFWS); and the California Bay-Delta Authority (CBDA) ERP staff, Science Program, and ERP Science Board (SB).

With guidance from the ERP SB, a Working Group of ERP implementing agency staff have developed an outline for the DRERIP and defined a process for obtaining scientific input. In addition, DFG has prepared approximately 50% of the plan, primarily consisting of background information.

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## Contents of the DRERIP

As currently envisioned the DRERIP will contain eight chapters, as well as associated appendices. Chapters 1 and 2, “Introduction” and “Scope and Basis for the Plan”, respectively, will identify the purpose of the plan, summarize the planning foundation, identify the scope of the plan, acknowledge that the plan will be based on contemporary scientific knowledge, and provide detail on how adaptive management will be incorporated.

Chapter 3, the “Environmental Setting: Baseline, Existing Conditions, and Trends” chapter, will provide information on the baseline, existing conditions, and trends for a number of resource areas, including flood management, the biological environment, agriculture, water use, diversions, altered flow regimes, land use, and recreation. This chapter will establish a baseline and trend for a number of these resource areas. In December 2002, a subsection of this chapter, Land Use, was released for public review and comment and can be found on the CBDA website designed specifically for the DRERIP (<http://calwater.ca.gov>).

The next chapter, Chapter 4, “Ecosystem Restoration Projects to Date”, will list ecosystem restoration projects that have been undertaken both by CALFED and others. In the future, information from this chapter will be used to assess overall progress of the ERP.

Chapter 5, “Delta ERP Actions in an Adaptive Management Context”, will present the scientific foundation for ecosystem restoration in the Delta. Existing ERP actions will be sorted into the categories of ecosystem processes, habitats, and stressors, and then evaluated by Action Teams. This procedure will also be used to identify the level of certainty or uncertainty associated with ERP actions (research, pilot scale, full-scale implementation), as discussed in greater detail below.

Chapter 6, “Implementation”, will address the avenues that are available for implementation. A process for establishing priorities will be presented as part of this chapter and the ERP actions will be prioritized accordingly.

Chapter 7, “Monitoring and Assessment”, will provide detail regarding the monitoring and assessment that will evaluate the ERP actions and refine them as needed over time.

Literature cited and persons consulted will comprise Chapter 8.

## Scientific Input Process

Preparation of Chapters 5, 6, and 7 of the DRERIP will require the development of scientific information to vet (evaluate) all Delta programmatic actions and targets contained in the applicable CALFED ERP planning documents. The programmatic actions (defined activities intended to achieve ecosystem restoration targets) and targets (qualitative or quantitative statements of a strategic objective) represent means to achieve the six ERP strategic goals and multiple objectives. Multi-Species Conservation Strategy (MSCS) conservation measures provide additional detail to ERP actions to achieve the restoration goals. These actions and targets are grouped into ecosystem elements (ecological processes, habitats, species, and stressors).

## Species Life History Conceptual Models

The process for vetting ERP actions, targets, and conservation measures will occur in several stages. The first stage is the development of species life history conceptual models by species experts, many of whom may be associated with IEP activities. These models will be developed for species within all the various ERP Plan objective categories, including “R” (objective=“recovery”), “r” (objective=“contribute to recovery”), listed “m” species (objective=“maintain”), and H (objective=“harvestable”) species. Critical habitats, processes, and stressors, as well as areas of uncertainty will be included in these models.

## Ecosystem Element Conceptual Models

The development of ecosystem element (ecological processes, habitats, and stressors) conceptual models will occur in the second stage and will rely on the work of Action Teams formed specifically for this work. These Action Teams are intended to be multi-disciplinary and will include individuals with expertise in hydrodynamics, geomorphology, soils, plants, fish, wildlife, invertebrates, ecology, and contaminants, to mention a few. As with the species conceptual models, experts who will be asked to participate in this effort will include IEP collaborators. The ERP SB will review the ecosystem element models.

## Vetting ERP Actions

The ERP actions will be vetted by the Action Teams in the third stage utilizing a process that will be developed by the ERP SB. The ERP actions that will be vetted will be taken from a number of ERP documents, including the Record of Decision, the ERPP Volumes I and II, the Strategic Plan, the Draft Stage 1 Implementation Plan, and the Water Quality Program Plan.

## Internal Oversight

An Adaptive Management Planning Team (AMPT) consisting of representatives from the Implementing Agencies—CBDA ERP and SB, and Science Program; co-leaders of the action teams; and an external scientist—will be formed to oversee the work of the species experts and Action Teams. This group will also be responsible for developing a process to prioritize the vetted ERP actions.

## Feasibility of ERP Actions

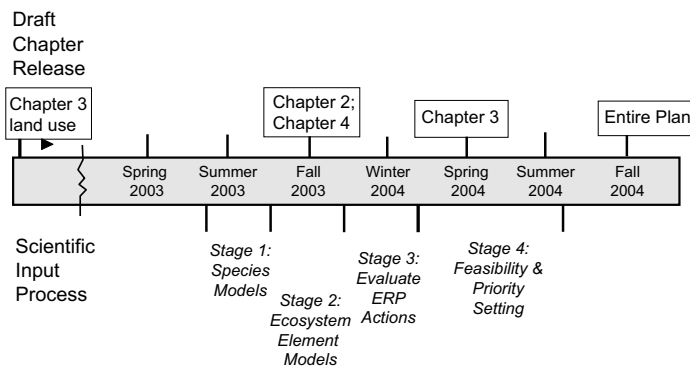
The last stage of the vetting process will be to assess the physical, financial, and socio-political feasibility of the ERP actions. This effort will also be undertaken by the Action Teams augmented with individuals possessing expertise in these areas. Once the feasibility of the actions has been assessed, the AMPT will prioritize the actions utilizing the process that they developed. The end product will then be reviewed and approved by the ERP Implementing Agency Managers.

## Peer Review

Peer review will occur throughout the entire scientific input process and will include review of the species and ecosystem element models, the vetting and priority setting processes, Chapter 5, and the completed draft of the DRE-RIP.

## Progress Updates

The scientific and stakeholder communities, as well as the public, will be informed of the progress of the DRE-RIP and its associated scientific input process through periodic presentations to the ERP SB, the ERP Implementing Agency Managers, the Agency Coordination Team, the Agency Stakeholder Ecosystem Team (ASET), the BDPAC Ecosystem Restoration Subcommittee, and the California Bay Delta Authority.



Hastings, 2003

**Figure 1 Draft DRERIP time line**

Figure 1 depicts the time line for preparing various chapters of the DRERIP, the final draft document, and the scientific input process. It is anticipated that a draft of the DRERIP will be available for public review and comment in December 2004. However, the details of the vetting process may change as the evaluation proceeds, thereby affecting the time line. The most current time line, as well as various DRERIP chapters, can be accessed via the DRERIP website (<http://calwater.ca.gov>).

## Acknowledgments

I would like to thank Lauren Hastings, Scott Cantrell, and Diane Windham for their comments on this article.

## Reference

Hastings, Lauren. 2003. Powerpoint presentation to the BDPAC Ecosystem Restoration Subcommittee. August 21.

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# CONTRIBUTED PAPERS

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## The Grind about Sonicated Chlorophyll (or: Did a Method Change in 1998 Affect EMP Chlorophyll Results?)

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### Introduction

Method continuity is an essential attribute of long-term monitoring programs such as the IEP Environmental Monitoring Program (EMP), ensuring data comparability over time and enabling comprehensive time series analyses. Nevertheless, sampling and analysis methods often undergo modifications to upgrade and modernize instrumentation, improve sampling or analytical efficiency, or to better comply with recognized standard methods. For each change in methods, method comparison tests should be conducted, and the results should be incorporated into metadata files to demonstrate continued data comparability. Here, we report the results of a recent year-long study comparing methods for sampling and extraction of chlorophyll *a* (CHL) used by the EMP before and after 1998, as well as from a historical comparison of CHL extraction methods conducted in 1978. CHL data collected by the EMP is one of the most frequently used and informative IEP data sets, as evidenced for example by its use in recent peer reviewed publications (for example, Jassby and others 2002, Kimmerer 2003). Ensuring the integrity of this data set and assuring its quality is thus of utmost importance.

Overall, we found good agreement between the historical and current EMP CHL methods. Where present, differences in methods were usually not greater than variability due to method imprecision. To properly evaluate differences between methods, it was particularly important to also have information on method precision (or imprecision). In the following, we present detailed analy-

ses of our method comparison results to show how we arrived at these conclusions and to serve as an example for future method comparison studies. To analyze the method comparison data, we used two statistical techniques commonly used in clinical studies (bias plots and Deming regression) that may not be familiar to many environmental scientists. These techniques are briefly explained in the Appendix. We hope that our study will inspire more comparisons of methods used by IEP monitoring programs and bring greater awareness to the critical issues of method validation and data comparability in long-term ecological studies.

### Study background, objectives, and approach

The EMP monitors water quality and lower trophic level organisms in the upper San Francisco Estuary (SFE; includes Delta, Suisun Bay, and San Pablo Bay). As part of this program, staff from the California Department of Water Resources (DWR) and the US Bureau of Reclamation (USBR) have conducted monthly measurements of CHL concentrations in discrete water samples since the program's inception in 1971-1972. From 1972 until February 1998, EMP staff (K. Triboli, DWR) extracted CHL from 400 ml grab samples using the historical EMP "sonication" method for pigment extraction with acetone followed by spectrophotometric analysis at a USBR laboratory facility. The sonication method employed a warm (58 °C) water bath and sonicator to disrupt cells followed by an incubation period at room temperature. Since 1998, larger sample volumes (500 to 1,000 ml, depending on concentrations of total suspended solids) have been concentrated for EMP CHL analyses, and a DWR staff chemist (M. Bettencourt) at DWR's EPA-certified Bryte Chemical Laboratory (Bryte Lab) has been responsible for carrying out the spectrophotometric CHL analyses closely following Standard Method 10200 H (APHA 1998), including the specified grinding procedures with acetone and incubation at 4 °C for pigment extraction and spectrophotometric pigment analysis.

In 2001-2002, we conducted a year-long method comparison study to ascertain the long-term comparability of EMP CHL data obtained with the historical EMP "400 ml Sonication" method and the current "1,000 ml grinding" method. Specifically, we wanted to answer the following questions across a range of CHL concentrations and environmental conditions in the upper SFE:

1. Did the change in EMP CHL methods affect CHL measurement precision, and if yes, how, and how much?
2. Did the change in CHL sample volume affect CHL results, and if yes, how, and how much?
3. Did the change in CHL sample extraction and analysis procedures affect CHL results, and if yes, how, and how much?

To answer these questions, replicated samples were taken monthly at four of nine EMP stations following a rotation schedule (Figure 1) from 11 June 2001 to 7 May 2002. Samples were processed following the test method procedures summarized in Table 1. Stations were chosen to capture the natural variability in upper SFE CHL concentrations, algal community composition, turbidity, and salinity levels. As part of routine EMP monitoring, we also recorded salinity, water temperature and phytoplankton community composition during the 2001-2002 study period. CHL analysis according to the historical 400 ml Sonication method was carried out by K. Triboli using the historical instrumentation at the USBR laboratory at 112 El Camino Plaza in Sacramento. These instruments had been in storage from 1998 through 2001 and were professionally serviced prior to this study. The 1,000 ml grinding and 400 ml grinding samples were processed at Bryte Lab by M. Bettencourt.

In addition to the CHL data collected in 2001-2002, we also reanalyzed previously unpublished CHL data collected by EMP personnel (D. Ball, USBR) in 1978 to compare grinding and sonication CHL extraction procedures. On June 12-15 and June 26-30, 1978, EMP staff collected duplicate samples from 21 and 25 EMP upper SFE sites, respectively (Figure 1). CHL in one sample of each duplicate sample pair was extracted using a grinding step, and in the other according to the sonication method. Sample volume was not reported, but was likely 400 ml, and pigment concentrations were measured spectrophotometrically.

In addition to using basic descriptive statistics with Shapiro-Wilk's W test for non-normality (Royston 1992), ordinary least squares regression, and analysis of variance with *post-hoc* Tukey pair-wise comparisons, we compared the results of the different methods using two techniques used in clinical method comparison studies: bias plots (also known as difference plots, ratio plots, or Bland-Altman plots) (Bland and Altman, 1986, 1999) and

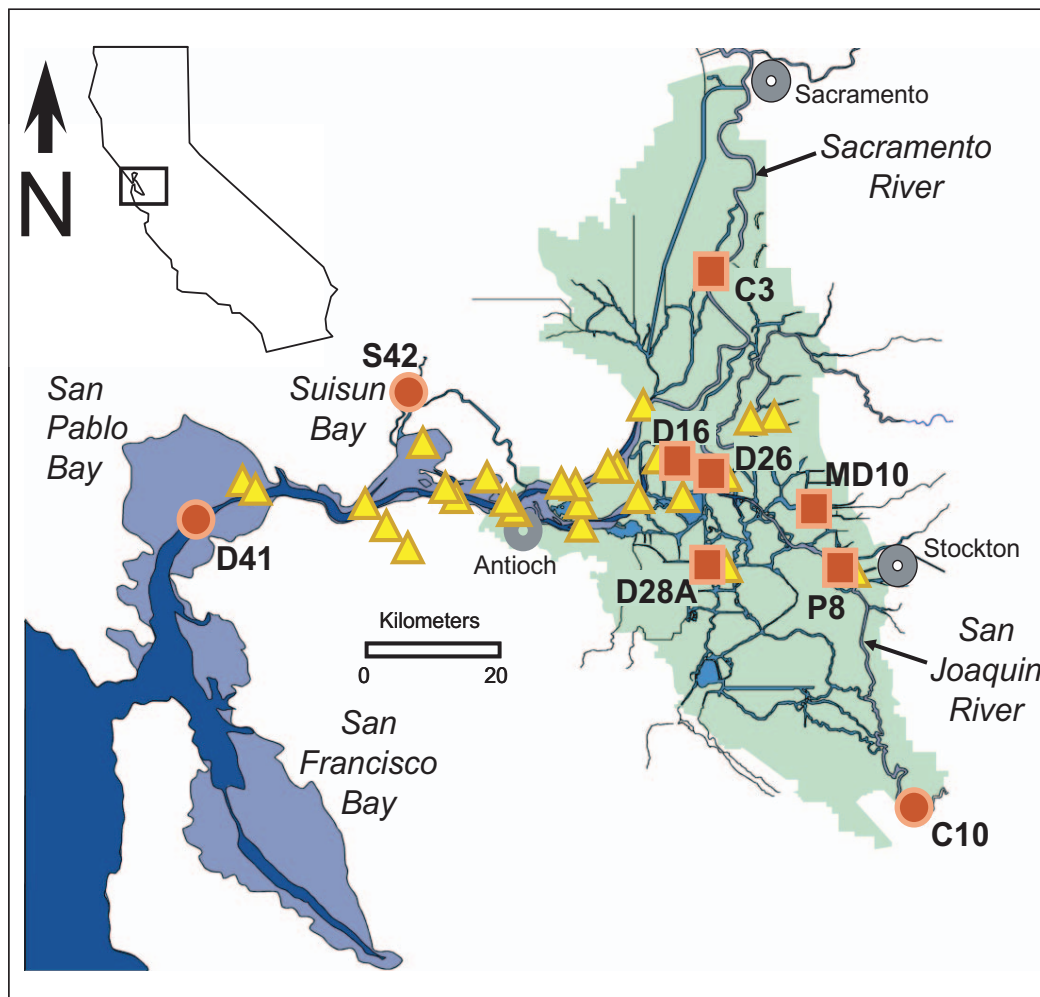
Deming regression (Linnet 1993, 1998). Reasons for choosing these techniques over the more familiar paired t-test and ordinary least squares regression approaches, and a brief explanation of each technique are given in the Appendix. Data analyses were carried out with Minitab™ (Version 13, 2000), Microsoft™ Excel 2002, and Analyze-it™ (Version 1.68, 2003) for Microsoft Excel.

## Results and Discussion

### Representativeness of the 2001-2002 Study Data

For the 2001-2002 study, we collected and successfully processed 132 CHL samples with up to three replicate analyses per sample during 48 sampling events for a total of 325 CHL analyses. CHL concentrations for all 132 samples ranged from 0.5 to 113  $\mu\text{g l}^{-1}$  (mean CHL = 10.7  $\mu\text{g l}^{-1}$ , standard deviation (SD) = 22.0  $\mu\text{g l}^{-1}$ , median CHL = 3.07  $\mu\text{g l}^{-1}$ ,  $n=132$ ) (Figure 2). 83% of the CHL concentrations were lower than 10  $\mu\text{g l}^{-1}$ , 70% were lower than 5  $\mu\text{g l}^{-1}$ , and 7% were lower than 1  $\mu\text{g l}^{-1}$ . All CHL concentrations greater than 10  $\mu\text{g l}^{-1}$  were measured at C10 (San Joaquin River at Vernalis) and P8 (San Joaquin River at Stockton). The lowest CHL concentrations were measured at D16 (San Joaquin River at Twitchell Island) and at S42 (Suisun Slough).

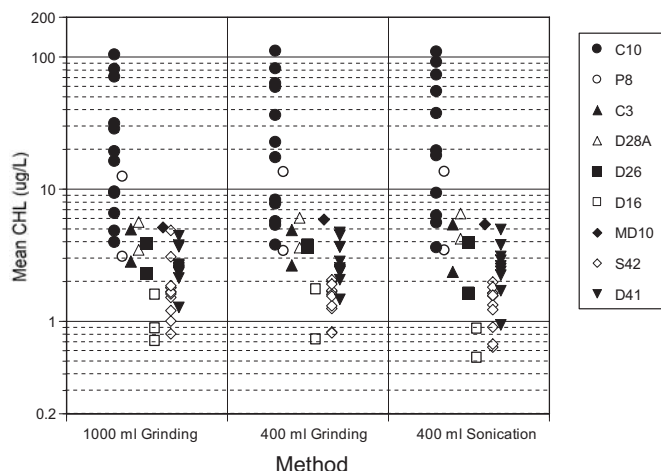
The range and distribution of CHL concentrations measured during our 2001-2002 study resembled CHL concentrations measured in the upper SFE over the last three decades: of 11,300 CHL concentrations measured by the EMP with the historical and the current methods, only 0.8% exceeded 100  $\mu\text{g l}^{-1}$ , while 80% were lower than 10  $\mu\text{g l}^{-1}$ , 66% were lower than 5  $\mu\text{g l}^{-1}$ , and 13% were lower than 1  $\mu\text{g l}^{-1}$  CHL. Observations of CHL concentrations greater than 100  $\mu\text{g l}^{-1}$  have been limited to the southern Delta and very dry ("dry" and especially "critically dry") years such as 1976-1977, 1991-1992, 1994, and 2001-2002, when maximum CHL concentrations of 370, 498, 247, and 119  $\mu\text{g l}^{-1}$ , respectively, were measured in the southern Delta. Our study period fell partially into the dry 2001-2002 period. This explains the occurrence of the high CHL concentrations measured at C10. During the three wetter years prior to this study (June 1998-May 2001), mean CHL concentrations of 105 duplicate samples collected by the EMP throughout the upper SFE using the current EMP method ranged from 0.4 to 45  $\mu\text{g l}^{-1}$ , with 90% of the mean CHL concentrations below 10  $\mu\text{g l}^{-1}$  and 75% below 5  $\mu\text{g l}^{-1}$ .



**Figure 1** EMP stations sampled as part of the 2001-2002 (red circles and squares) and 1978 (yellow triangles) CHL method comparison studies. Circles: fixed stations sampled each month; Squares: rotating stations, one station sampled each month.

**Table 1** Study design: Test methods and questions.

CHL Test Method:	“1000 ml Grinding”	“400 ml Grinding”	“400 ml Sonication”	“1978 Grinding”	“1978 Sonication”
Primary sample purpose	EMP Monitoring	Method comparison	Method comparison	Method comparison	Method comparison
Sampling period	6/2001 - 5/2002	6/2001 - 5/2002	6/2001 - 5/2002	6/1978	6/1978
Number of samples	42	44	46	46	46
Replicates per sample	1-2	3	3	1	1
Sample volume	1000 ml	400 ml	400 ml	400 ml?	400 ml?
Pigment extraction	Grinding	Grinding	Sonication	Grinding	Sonication
Laboratory	DWR Bryte Lab	DWR Bryte Lab	USBR Lab	USBR Lab	USBR Lab
Instrumentation	Post-98	Post-98	Pre-98	1978	1978
Analyst	M. Bettencourt	M. Bettencourt	K. Triboli	D. Ball	D. Ball
Questions:	↓	↓	↓	↓	↓
Question 1	Sampling & Analysis Precision				
Question 2	Sample Volume				
Question 3		Pigment Extraction			
				Pigment Extraction	



**Figure 2** CHL concentrations measured in 2001-2002 at the nine EMP stations shown in Figure 1 and with the three test methods described in Table 1.

Water temperatures ( $9.9^{\circ}\text{C}$  to  $26.7^{\circ}\text{C}$ ), EC values ( $0.2\text{ mS/cm}$  to  $45\text{ mS/cm}$ ), and turbidity ( $2.6$  to  $52\text{ NTU}$ ) associated with the CHL samples collected during this study spanned the ranges commonly found in the upper San Francisco Estuary (CDWR 1996). Also typical for the upper SFE, the phytoplankton community in samples taken simultaneously with the CHL samples was generally dominated by diatoms (especially centrics), miscellaneous flagellates, and chlorophytes. We thus effectively captured the natural variability in CHL concentrations and phytoplankton composition as well as in important factors responsible for this variability and potentially affecting CHL analyses. Conclusions from the 2001-2002 study should thus be reasonably applicable to the long-term EMP CHL data set.

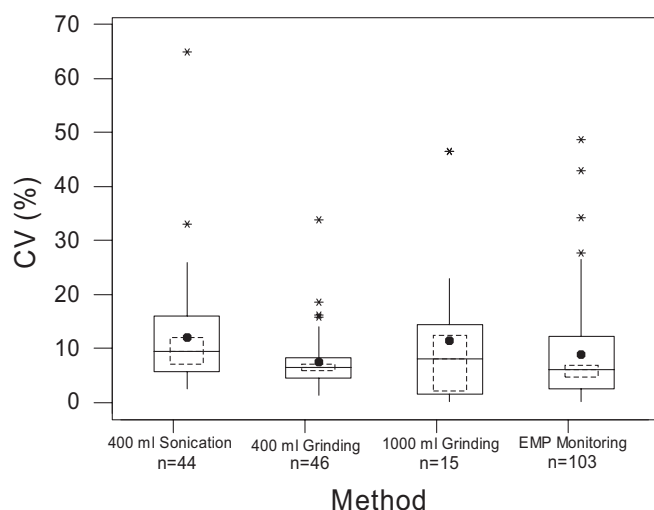
#### Question 1. Method Precision

For the three 2001-2002 CHL test methods, standard deviations of replicate CHL measurements increased with increasing CHL concentrations, and we thus used coefficients of variation (CV) to compare method precision (Figure 3, see also Appendix). The resulting CV (Figure 3) were unrelated to CHL concentrations (ordinary least-squares linear regression:  $n=208$ ,  $P=0.08$ ,  $R^2=0.01$ ), but not normally distributed. Since fewer replicates ( $n=15$ ) were collected and analyzed according to the 1,000 ml grinding method than for the other two methods, we also calculated CV for 103 duplicate CHL samples collected and analyzed according to the current EMP 1,000 ml grinding method during routine EMP monitoring from June 1998 to May 2001 (Figure 3: “EMP Monitoring”).

Most CV were below 20% with mean CV near 10% and a somewhat lower median CV for all four methods. The 400 ml grinding method had the least variable CV and the lowest mean CV (7.38%) while EMP Monitoring had the lowest median CV (6.0%). The highest mean CV (11.9%) and median CV (9.3%) were observed for the 400 ml sonication method. The confidence intervals around the mean and median were largest for the 1,000 ml grinding test method, which was likely due to the low number of replicate measurements. To test for differences between mean CV for the three test methods and EMP monitoring, we normalized the CV through log-transformation and performed a one-way ANOVA followed by a pairwise comparison of means using the Tukey method. We found that there was a significant overall difference in CV for all four methods ( $n=208$ ,  $P=0.02$ ) and that the mean CV for the 400 ml Sonication method was significantly higher than the EMP monitoring CV, but there were no significant differences between the mean CV of all other method pairs. The 1998 change in CHL extraction methods thus appreciably improved the precision of EMP CHL measurements, while the change in volume did not significantly affect precision. Reducing the current sample volume from 1,000 ml back to 400 ml would not increase and might in fact slightly improve precision. Overall, CV were quite high, and improving precision should be a goal for future EMP CHL analyses.

For all three test methods and EMP monitoring combined, the mean CV was 9.2% and the median 6.5% ( $SD=9.1\%$ , 95% Confidence Interval (CI) for the mean  $CV=7.9\%$  to  $10.4\%$ ,  $n=208$ ). For a CHL concentration of  $10\text{ }\mu\text{g l}^{-1}$ , this means that irrespective of method, the expected mean method imprecision is  $\pm 0.92\text{ }\mu\text{g l}^{-1}$  CHL ( $SD=10\text{ }\mu\text{g l}^{-1} * 9.2\%=0.92\text{ }\mu\text{g l}^{-1}$ ), and 95% of all measurements would be expected to fall into a reference interval of  $10\text{ }\mu\text{g l}^{-1} \pm 1.96 * SD$ , i.e. between about  $8.2$  and  $11.8\text{ }\mu\text{g l}^{-1}$  CHL, assuming a normal distribution of replicated CHL measurements. For a concentration of  $5\text{ }\mu\text{g l}^{-1}$ , mean method imprecision would be  $\pm 0.46\text{ }\mu\text{g l}^{-1}$  CHL and most measurements would be between  $4.1$  and  $5.9\text{ }\mu\text{g l}^{-1}$ .





**Figure 3** Box plot<sup>1</sup> of coefficients of variation (CV, in %) for replicate sample analyses with the three 2001-2002 test methods and according to the 1,000 ml grinding method during two years prior to the study period (“EMP monitoring”).

#### Question 2. Sample Concentration Procedures.

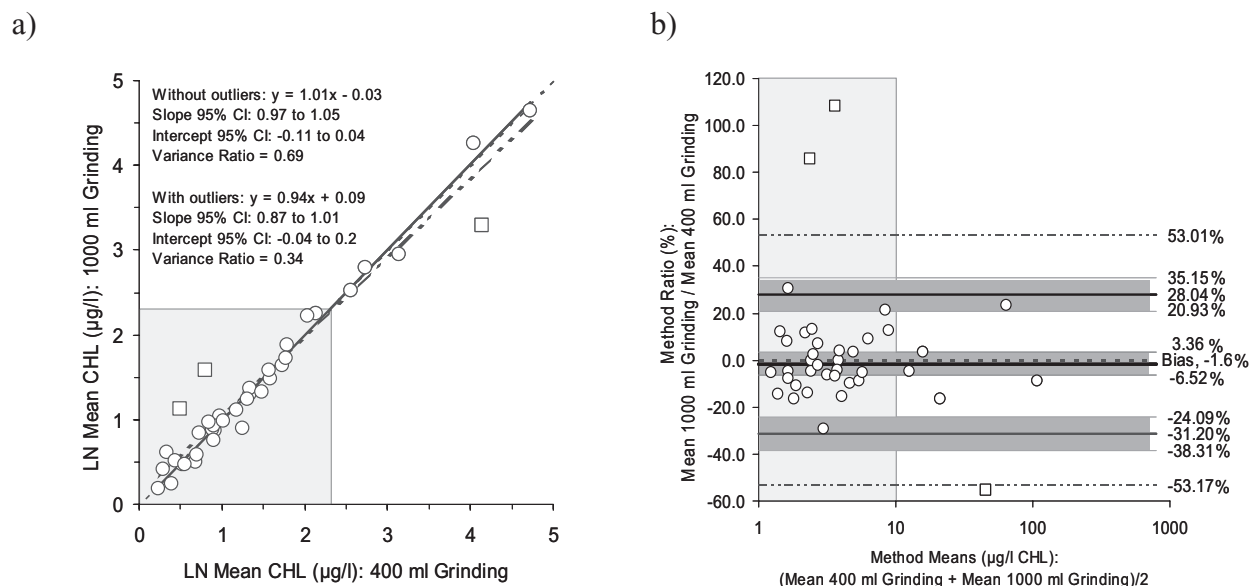
During 39 of the 48 sampling events of the 2001-2002 study, samples with volumes of 1,000 ml (single or duplicate samples, 1,000 ml grinding method) and 400 ml (triplicate samples, 400 ml grinding method) were simultaneously concentrated onto filters. All filters were subsequently analyzed at Bryte Lab using to the same procedures.

Overall, the differences between the results achieved with the two sample concentration procedures were not very large (mean absolute difference=0.15  $\mu\text{g l}^{-1}$  CHL, standard deviation=0.19  $\mu\text{g l}^{-1}$ , median=0.09  $\mu\text{g l}^{-1}$ , range 0-0.85  $\mu\text{g l}^{-1}$ ,  $n=39$ ). The differences increased over the range of measured CHL concentrations and were not normally distributed. Log-transformation failed to remedy this situation due to three outliers. We thus removed the three outliers and proceeded to carry out the analyses with the log-transformed data. However, while the results without outliers are statistically correct since all assumptions

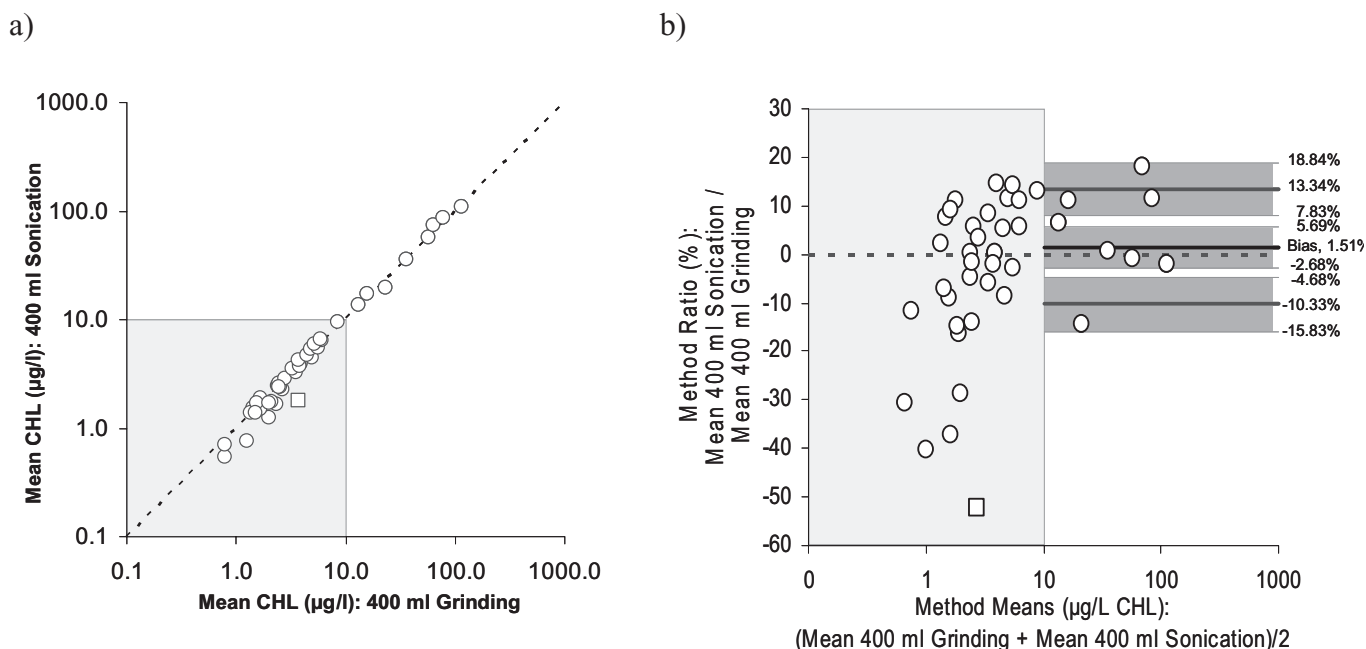
about the data were met, they present a somewhat idealized situation because we had no *a priori* reason to doubt the validity of these three anomalous observations. In Figure 4 we thus present Deming regression results and a bias plot for the log-transformed data with and without the three outliers (indicated by squares).

According to a Deming regression, the CHL results from the two methods were linearly related to each other and statistically indistinguishable (slope 95% confidence interval (CI) includes 1; intercept 95% CI includes 0; see Appendix for caveats in interpreting regression-based significance test results). The bias plot (a “ratio plot” of method ratios (mean 1,000 ml grinding CHL / mean 400 ml grinding CHL) versus the methods means, see Appendix 1) also shows that the methods deliver similar results across the range of measured CHL concentrations (geometric mean bias ratio (-1.6%) close to 0%, no relationship between method ratios and means). Without the three outliers, method ratios ranged from -29.5% to 30.6%. According to the calculated 95% limits of agreement (LOA), 95% of method ratios are expected to lie within -31.2% and 28.0%. This means that for a mean CHL concentration of 10  $\mu\text{g l}^{-1}$ , the 1,000 ml grinding method would on average deliver a result of 9.92  $\mu\text{g l}^{-1}$  CHL and the 400 ml grinding method would yield 10.08  $\mu\text{g l}^{-1}$  CHL, and 95% of all measurements would fall between 8.15 and 11.23  $\mu\text{g l}^{-1}$  CHL for the 1,000 ml grinding method and 8.77 and 11.85  $\mu\text{g l}^{-1}$  CHL for the 400 ml grinding method (method ratio -31.2%: 8.15  $\mu\text{g l}^{-1}$  / 11.85  $\mu\text{g l}^{-1}$  CHL; method ratio 28.0%: 11.23  $\mu\text{g l}^{-1}$  / 8.77  $\mu\text{g l}^{-1}$  CHL). These 95% LOA estimates and associated CHL concentrations are of a similar magnitude as the method imprecision described above and most of the differences between CHL results measured with the two methods can thus likely be attributed to method imprecision. In conclusion, sample volumes of 400 ml and 1,000 ml deliver indistinguishable CHL results with most differences likely resulting from method imprecision rather than from method differences. The 1998 change in sample volumes thus had no effect on CHL results. No data correction is necessary in the long-term data set following the change in sample volume, and sample volumes could be reduced back to 400 ml to reduce sample processing (filtration) time.

1. Box plot explanation: The bottoms of the solid boxes are the first quartile and the tops are at the third quartile values for each data category (method). Lines across these boxes show the median, and the mean value is denoted by a solid circle. The “whiskers” extend to the highest and lowest values that are not more than 1.5 times away from the middle 50% of the data. Outliers are outside of these limits and indicated by stars. The tops and bottoms of the dotted boxes show the extent of the 95% confidence limits for the associated medians.



**Figure 4** Comparison of log-transformed CHL concentrations measured with the 1,000 ml grinding method and with the 400 ml grinding method. Shaded box: values below  $10 \mu\text{g l}^{-1}$ . Circles: normally distributed differences in mean CHL concentrations. Square symbols: outliers. Dashed line: identity line. a) Results of Deming regression with (double-dashed line) and without (solid line) three outliers. b) Bias plot of ratios (in %) versus means of CHL concentrations measured with the two methods. The bias plot shows the bias (geometric mean method ratio) and associated 95% limits of agreement (solid horizontal lines) with 95% confidence intervals (shaded horizontal bands) calculated without the three outliers. It also shows 95% limits of agreement (double-dashed lines) calculated with the three outliers (bias=-0.08%).



**Figure 5** Comparison of CHL concentrations measured with the 400 ml grinding method and with the 400 ml Sonication method. Shaded vertical box: values below  $10 \mu\text{g l}^{-1}$ . Square symbol: outlier. Dashed line: identity line. a) Scatter plot of mean CHL concentrations measured with the 400 ml grinding and the 400 ml Sonication methods. b) Bias plot of ratios (in %) versus means of CHL concentrations measured with the 400 ml Sonication and the 400 ml grinding method. For CHL means above  $10 \mu\text{g l}^{-1}$ , this ratio plot shows the bias (geometric mean method ratio) and associated 95% limits of agreement (solid horizontal lines) with 95% confidence intervals (shaded horizontal bands) calculated without the outlier.

### Question 3. Sample extraction and analysis procedures

During 42 of the 48 sampling events in 2001-2002, three of six simultaneously collected samples were processed and analyzed either according to the 400 ml Sonication method or according to the 400 ml grinding method. In 81% of the samples, CHL concentrations were lower than  $10 \mu\text{g l}^{-1}$ . Overall, the differences between the results achieved with the two sample concentration procedures were again not very large (mean absolute difference =  $0.98 \mu\text{g l}^{-1}$  CHL,  $\text{SD} = 2.20 \mu\text{g l}^{-1}$ , median =  $0.29 \mu\text{g l}^{-1}$ , range  $0\text{--}11.33 \mu\text{g l}^{-1}$ ,  $n=42$ ). As for Question 2, CHL differences between methods increased with increasing CHL concentrations and were not normally distributed. Log-transformation again failed to normalize the data. However, in contrast to the Question 2 data, here this was not due to a few outliers randomly distributed across the data range. Instead, it was caused by a proportional relationship between CHL method means and differences above but not below  $10 \mu\text{g l}^{-1}$ . While this is hardly noticeable in the scatter plot of CHL results for the two methods (Figure 5a), the bias (ratio) plot for the log transformed data (Figure 5b) clearly illustrates these different relationships between CHL means and method differences above and below  $10 \mu\text{g l}^{-1}$  CHL. We thus separated the data set into CHL concentrations above and below  $10 \mu\text{g l}^{-1}$  CHL. After removing one outlier (square symbol in Figures 5 and 6), differences between methods for the less than  $10 \mu\text{g l}^{-1}$  CHL data set were normally distributed without log-transformation. Above  $10 \mu\text{g l}^{-1}$ , all assumptions were met for the log-transformed data.

For log-transformed CHL concentrations greater than  $10 \mu\text{g l}^{-1}$ , Deming regression showed a linear relationship ( $\ln(400 \text{ ml Sonication}) = 1.02 * \ln(400 \text{ ml Grinding}) - 0.04$ ) and no statistical difference between the two methods. Method ratios (Sonication/Grinding; Figure 5) ranged from -14.4% to 17.9%. According to the LOA, 95% of all method ratios are expected to lie within -10.3% and 18.3% with an geometric mean ratio of 1.5%. For a mean CHL concentration of  $50 \mu\text{g l}^{-1}$ , the 400 ml Sonication method would thus on average provide a result of  $50.4 \mu\text{g l}^{-1}$  CHL and 95% of all measurements would fall between  $47.3$  and  $54.2 \mu\text{g l}^{-1}$  CHL. The 400 ml grinding method would on average deliver a result of  $49.6 \mu\text{g l}^{-1}$  CHL and 95% of all measurements would fall between  $45.8$  and  $52.7 \mu\text{g l}^{-1}$  CHL. As for Question 2, these variations are of a similar magnitude as the method imprecision described above and most of the differences between CHL results measured with the two methods can thus likely be

attributed to method imprecision. For CHL concentrations above  $10 \mu\text{g l}^{-1}$ , the 400 ml Sonication and the 400 ml grinding method thus deliver indistinguishable CHL concentrations with observed differences likely largely due to method imprecision.

According to a Deming regression with untransformed data, CHL concentrations below  $10 \mu\text{g l}^{-1}$ , were linearly related (without outlier:  $400 \text{ ml Sonication} = 1.15 * (400 \text{ ml Grinding}) - 0.45$ ) and there was a proportional (slope different from 1) as well as a constant (intercept different from 0) statistical difference between the two methods (Figure 6 a). Grinding usually delivered higher CHL results than sonication in the lower CHL concentration range (below about  $3 \mu\text{g l}^{-1}$  CHL), but for higher CHL values this relationship was reversed. This means that the 400 ml Sonication method is somewhat more sensitive in detecting differences in CHL concentrations than the 400 ml grinding method for CHL concentrations below  $10 \mu\text{g l}^{-1}$ , although this does not mean that the results are also more accurate.

The proportional relationship between mean CHL concentrations and differences between methods is more clearly visible in the bias plot (Figure 6 b, a “difference plot”). While the bias is near zero (mean difference =  $0.02 \mu\text{g l}^{-1}$  CHL), the 95% LOA calculated for the method differences are quite wide ( $0.02 \pm 1.08 \mu\text{g l}^{-1}$  CHL), but this variation in method differences is similar to the variation in CHL results expected due to method imprecision, at least for CHL concentrations greater than about  $3 \mu\text{g l}^{-1}$ . Perhaps a better way to calculate the mean difference and 95% LOA in this case is to use a linear regression approach. This better captures the proportional relationship between means and differences (see Appendix). Using this approach, bias in relation to the method mean is expressed as

$$\text{Mean Method Difference (Sonication-Grinding)} = 0.14 * (\text{Method Mean}) - 0.43$$

and the 95% LOA around this bias are narrower (bias  $\pm 0.58 \mu\text{g l}^{-1}$  CHL) than above (Figure 5 b), double-dashed lines). On average the 400 ml Sonication method thus delivers 14% greater results than the 400 ml grinding method, but this difference is lowered by a constant  $0.43 \mu\text{g l}^{-1}$  CHL. This closely resembles the results of the Deming regression. For a CHL concentration of  $5 \mu\text{g l}^{-1}$ , the expected mean difference (Sonication-Grinding) between the two methods would thus be  $0.27 \pm 0.58 \mu\text{g l}^{-1}$

CHL. The Sonication method would be expected to deliver mean CHL concentrations of  $5.135 \mu\text{g l}^{-1}$  and 95% of all Sonication results would be expected to lie between  $4.845$  and  $5.425 \mu\text{g l}^{-1}$  CHL. The grinding method would on average yield  $4.865 \mu\text{g l}^{-1}$  CHL and 95% of all grinding results would be expected to lie between  $4.845$  and  $5.290 \mu\text{g l}^{-1}$  CHL. Grinding results would on average equal Sonication results at a mean chlorophyll concentration of  $3.07 \mu\text{g l}^{-1}$  and below this concentration they would be greater than Sonication results.

In summary, above  $10 \mu\text{g l}^{-1}$  CHL, the 400 ml Sonication and the 400 ml grinding method yield statistically indistinguishable CHL concentrations with the expected magnitude of differences between methods similar to the variability in CHL results due to method imprecision. The 1998 change in laboratory methods thus had no effect on CHL results, and in the long-term data set, no data correction is necessary for CHL concentrations above  $10 \mu\text{g l}^{-1}$ . For CHL concentrations below  $10 \mu\text{g l}^{-1}$  CHL, there were both significant proportional and constant differences between the two methods, indicating that the 400 ml Sonication method is somewhat more sensitive (though not necessarily more accurate) in detecting differences in CHL concentrations for CHL concentrations below  $10 \mu\text{g l}^{-1}$  than the 400 ml grinding method. The equations from the Deming regression (but see Appendix) or the linear regression of differences versus means could be used to correct the data below  $10 \mu\text{g l}^{-1}$  CHL in the long-term EMP CHL data set (that is, Sonication CHL =  $1.1 * \text{grinding CHL} - 0.4$ , or grinding CHL =  $0.9 * \text{Sonication CHL} + 0.4$ ). However, except at very low (less than about  $3 \mu\text{g l}^{-1}$ ) CHL concentrations, the differences between methods were not greater than what would be expected simply due to method imprecision, making this correction generally unnecessary. The somewhat greater sensitivity of the Sonication method might be a reason for its greater level of imprecision compared to the grinding method.

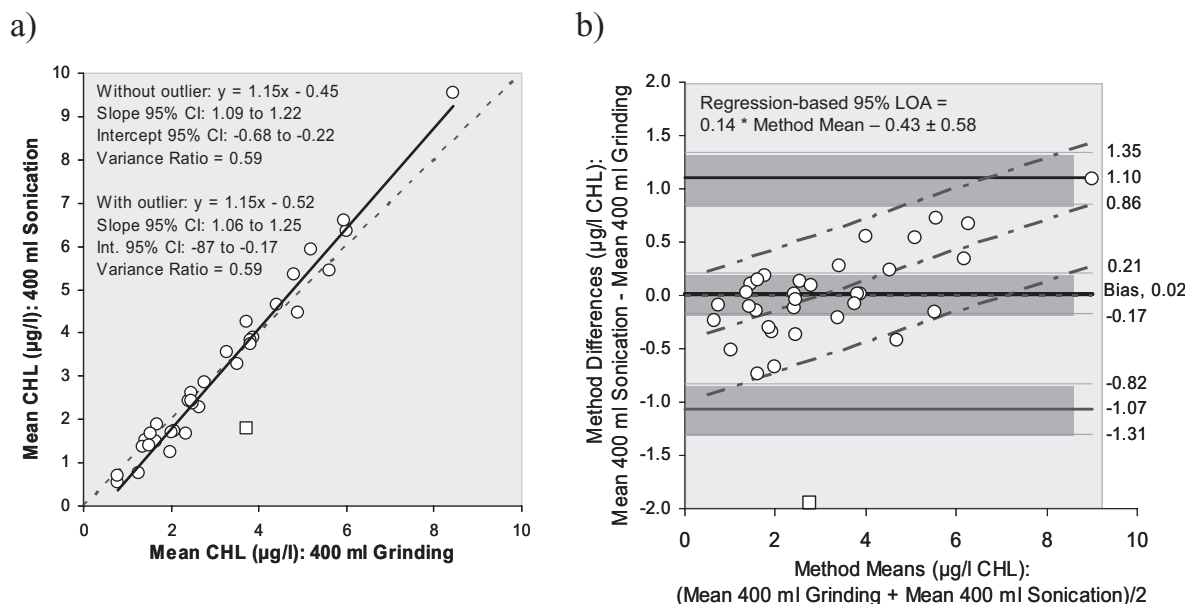
#### *1978 CHL method comparison*

CHL concentrations in the 46 duplicate CHL samples collected in June 1978 and extracted using either a grinding or a sonication step ranged from  $1.4$  to  $14.1 \mu\text{g l}^{-1}$  (mean CHL =  $7.1 \mu\text{g l}^{-1}$ ,  $SD = 3.0 \mu\text{g l}^{-1}$ , median CHL =  $6.9 \mu\text{g l}^{-1}$ ,  $n = 92$ ). While the CHL concentrations for each method were normally distributed, the differences between methods were not because of four outliers (Figure 7, squares). Deming regression showed that CHL concentrations were linearly related (without outliers:  $1978 \text{ Sonication} = 0.9 * (1978 \text{ Grinding}) + 0.7$ ). As for

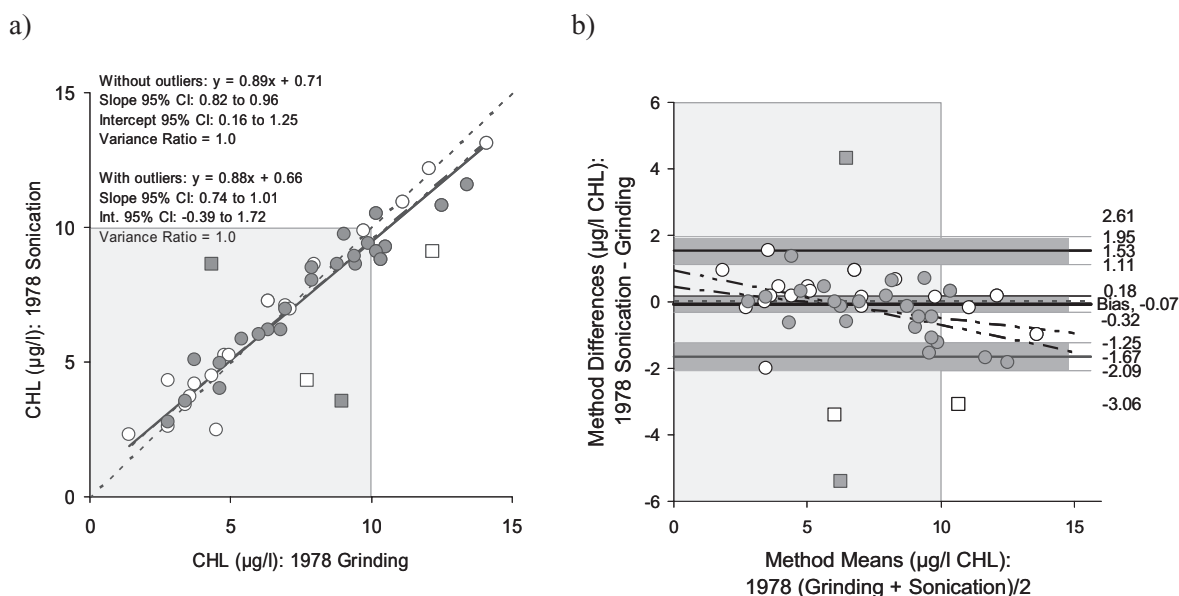
question 3, above, there was a proportional as well as a constant statistical difference between the two methods for these fairly low mean CHL concentrations (Figure 7 a). These differences were more pronounced for the results from the second sampling event, as can be seen more clearly in the difference plot (Figure 7 b, dashed linear regression lines). Interestingly, in contrast to 2001-2002, in 1978 the Sonication method delivered higher values at low CHL concentrations and lower values at higher concentrations, i.e. appeared less sensitive than the grinding method. While the mean difference between method results is again very close to zero (bias =  $-0.07 \mu\text{g l}^{-1}$  CHL), even without the four outliers the 95% LOA (Figure 7 b) are wider than for the 2001-2 Grinding-Sonication comparison and greater than what would be expected based solely on method imprecision calculated for the 2001-2002 study. Unfortunately, there are no replicated measurements for the 1978 method comparison data set and for EMP monitoring in the 1970s. Method precision at that time as well as its influence on the observed or expected differences between methods can thus not be properly evaluated. This underscores the importance of assessing method precision along with method agreement. Nevertheless, the 1978 comparison provides further evidence that sonication and grinding deliver consistent CHL results, and that this was the case in the early days of the EMP and is still the case today.

#### **Conclusions**

The quality of the information that can be gained from the IEP's long-term data sets depends entirely on the quality of the data, which in turn depends on method validity. Method validation, including method comparison studies, should be taken as seriously and carried out as rigorously as all other scientific undertakings. An essential prerequisite for method comparison studies is information about the precision of the compared methods, because method imprecision limits the possible amount of agreement between methods and can mask real differences between methods. Thus, repeated analyses of the same samples should always be part of method comparison studies. Statistical techniques developed for clinical applications can be helpful for analyzing and visualizing the results from environmental method comparisons. Overall, the historical EMP "Sonication" method for CHL analysis was less precise than the current "grinding" method, but had somewhat greater sensitivity in detecting differences in CHL concentrations below  $10 \mu\text{g l}^{-1}$  CHL. The 1998 change in sample volume from 400 ml to 1,000 ml had no effect on



**Figure 6** Comparison of CHL concentrations below  $10 \mu\text{l}^{-1}$  measured with the 400 ml grinding method and with the 400 ml Sonication method. Symbols, boxes, and lines as in Figure 5. a) Deming regression (solid line) with and without outlier, dashed line: identity line. b) Bias plot of differences versus mean CHL concentrations (calculations without outlier). This difference plot shows the bias (mean difference) and associated 95% limits of agreement (solid horizontal lines) with 95% confidence intervals (shaded horizontal bands). In addition it shows a linear regression-based mean difference (bias= $0.14 * \text{Method Mean} - 0.43$ ) and 95% limits of agreement (double-dashed lines).



**Figure 7** Comparison of 1978 CHL concentrations measured with the grinding method and with the Sonication method. Open symbols: samples collected June 12-15, 1978. Solid symbols: samples collected June 26-30, 1978. Circles: normally distributed CHL differences. Squares: outliers. Shaded vertical box: values below  $10 \mu\text{l}^{-1}$ . Dashed line: identity line. (a) Deming regression with (double-dashed line) and without (solid line) outlier; (b) Bias plot of differences versus means of CHL concentrations measured with the 1978 Sonication and the 1978 grinding methods. This difference plot shows the bias (mean difference) and limits of agreement (solid horizontal lines) with confidence intervals (shaded horizontal bands) calculated without the four outliers. In addition the double-dashed lines show linear regression-based mean differences for the two sampling events: — - — June 12-15, 1978, and — . . — June 26-30, 1978.

CHL results, and sample volume should be reduced back to 400 ml to reduce sample processing time. This might also enhance method precision. Increasing method precision from a median CV near 10% to a median CV of no more than 5% should be a goal for future EMP CHL measurements. At the current level of precision, most observed differences between methods were of similar magnitudes as method imprecision, and consequently real differences between methods could not be unequivocally distinguished. Moreover, in all cases, including the 1978 method comparison, the mean difference between methods was near zero, and only the magnitudes of individual differences changed across the measurement range. Data correction in response to the 1998 method change is thus unwarranted, and the EMP CHL data set can be used in its entirety for long-term time series analyses.

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## Appendix: Method comparison statistics

When comparing methods, an estimate of the precision of each method is an essential prerequisite. Precision is the reproducibility of results for replicate samples, and analogous to “within-group variation” or “error variance” commonly encountered in ANOVA tables. Information on the precision of the test methods is important because method precision (or imprecision) limits the amount of agreement that can possibly be achieved between the methods, or the significance of detectable differences between methods. It can also mask real differences between methods in graphical data explorations. Replicated measurements are thus an important requirement for method comparisons. Method precision can be expressed as the standard deviation (*SD*) of replicate measurements. However, in many cases (including in our 2001-2002 study) *SDs* increase with increasing measurement concen-

trations. In these cases, the coefficient of variation (*CV*, commonly reported in percent of the mean) can be used to compare precision of different methods across a range of measurement magnitudes. The *CV* is the *SD* divided by the associated mean concentration of the replicate measurements. *CV* are thus usually unrelated to measurement magnitude. The acceptable level of *CV* is a matter of analytical judgment and depends on the analytical method and the analyte. In water chemistry analyses, *CV* of up to 5 or 10% are often considered acceptable.

Differences between methods can be random or systematic. Systematic differences can be either constant (“constant bias”. For example, method A always delivers higher results than method B), or proportional to the magnitude of the results (“proportional bias”. for example, method A delivers lower results than method B in the low data range, but higher results in the higher data range), or both.

Traditionally, a series of simultaneous measurements on identical samples carried out with different methods might be compared using a paired t-test (or an ANOVA, if more than two methods are compared) to test the null-hypothesis that the mean difference between method results is zero. This test detects a constant difference between the method means, but unfortunately fails to detect proportional differences. Furthermore, larger systematic differences between method results increase the standard error of the mean difference and thus actually reduce the chance of detecting a difference between the method means. Also, like for all significance tests, the ability to detect difference is highly dependent on the number of observations and also depends on the magnitude of the scale of measurements. Moreover, this (or any other) type of significance test does not give any information about how well individual observations agree.

Method comparison has received much attention in clinical studies where the agreement between methods (for example, measurement of blood glucose levels) can mean life or death for patients. In response to the limitations of the more traditional comparison techniques, clinical statisticians have mostly turned to two types of approaches, a regression-based and a graphical approach (Magari 2002). Both approaches emphasize the type of relationship (constant versus systematic bias, etc.) between the results achieved with two methods. However, while the regression-based approach includes statistical significance testing and modeling of the relationship

between results from two methods, the graphical approach refrains from any significance tests and instead focuses on the actual differences between individual pairs of results, with interpretation of method agreement largely based on clinical judgment. Regression-based approaches appear to be best suited for assessing if two methods agree at all and to cross-calibrate methods, while the graphical approach gives a better understanding about how closely two methods agree (or by how much they differ). Somewhat surprisingly, a search of the ecological literature revealed few examples of method comparison studies with statistical analysis of the results and only one study employing bias plots (Campana and others 1995, for otolith-based fish aging comparisons).

The regression-based method comparison approach currently most often recommended for clinical studies is the so-called “Deming regression” (Linnet 1990, 1998; Martin 2000), although it has also received a good deal of criticism (for example, Dunn and Roberts 1999, Stöckl and others 1999). Deming regression is a model II parametric regression technique similar to a standardized principal component analysis. In contrast to ordinary least squares regression (that is, model I regression, allows error only in the dependent variable), this technique allows for error in both variables and accounts for these errors by means of a constant variance ratio of errors (imprecision) for each method. If method imprecision is unknown, it is assumed to be the same for each method and the variance ratio is thus 1 (see Figure 7a). The variance ratio determines the angle for minimizing the sum of squared deviations along the regression line (for calculation of the variance ratio, see Linnet 1998, Appendix). Because both methods in method comparison studies are usually subject to error (due to method imprecision), this type of regression seems appropriate to explore the relationship of the method results and test the null hypotheses of no constant bias (intercept=0) and no proportional bias (slope=1). However, as is the case for all model II regression techniques, it is less appropriate for prediction of method B results from method A, since this type of regression is designed to give a functional equation that best describes the joint variation of two random variables by identifying a mutual slope and y-intercept, and not to predict values of method B given a value for method A (Sokal and Rohlf 1995). For prediction or “method cross-calibration,” ordinary least squares regression is thus more appropriate, but needs to be carried out separately to predict method B results from method A and method A results from method B. Also note that the regression (or

correlation) coefficients resulting from these regression analyses should not be used to evaluate method agreement since they strongly depend on sample size and are thus quite meaningless in this context. Deming regression assumes a normal distribution of imprecision in measurements for each method and constant variances over the measurement range. When repeated (replicate) measurements are available for each sample and each method, the means of the repeated measurements are used for the regression. In addition to the parametric Deming regression approach, a non-parametric regression approach, “Passing-Bablok” regression (Passing and Bablok 1983), is now also commonly used in clinical method comparison studies.

Unfortunately, Deming regression (and any other type of regression) is still subject to some of the limitations in method comparison studies mentioned above. In particular, the hypothesis tests are affected by the magnitude of differences between method results (large individual differences can reduce the chance of detecting significant overall differences), the number of observations, and the magnitude of the scale of measurements. Moreover, while methods designed to measure the same variable more often than not yield significantly similar results, there may still be large individual differences between the different methods. This can be seen in the regression plot, but the data points are usually quite close to the regression line and the exact nature of the differences is difficult to perceive. Bland and Altman (1986, 1999) thus proposed an alternative graphical approach to evaluating method comparison data. This approach is more geared toward assessing how well two methods agree with each other than to detecting overall differences. The “difference” or “bias” plot is somewhat similar to a residual plot familiar from regression analysis, but instead of plotting the differences between observations and predicted values, the bias plot shows the differences between the observations from the two methods (see Figure 6 and 7 b). As for the regression approach, repeated (replicate) measurements are averaged and then the differences between the mean measurements of each method are calculated and plotted.

The bias plot approach visually emphasizes the differences between individual pairs of observations over the range of measurements and also shows the types of differences (constant or proportional) between methods (compare for example Figures 6 a and 6 b). A mean difference, i.e. the “bias,” over the measurement scale can be calculated, along with a reference interval into which 95% of

all observations are expected to fall, the “95% limits of agreement” (95% LOA). For normally distributed differences and a constant bias, the 95% LOA can be calculated as  $\text{bias} \pm 1.96 * SD_{\text{differences}}$ . In addition, 95% confidence intervals can be calculated for the bias and 95% LOA. If repeated measurements were made, the 95% LOA estimates are corrected to include the additional variance due to method imprecision (see Bland and Altman, 1999, for calculations). If there is a constant bias, it can be used to “correct” values measured with method A for the difference in measurements by method B, and the 95% LOA give a sense of the range of potential values if the other method were used. Further interpretation of the bias and associated 95% LOA depends on the particular methods to be compared, and decisions about an acceptable level of method agreement should best be made before conducting the method comparison study. In general, a substantial bias is less of a problem than large 95% LOAs, since it is easily possible to correct for the bias, while this cannot be accomplished for highly variable differences between methods. When precision estimates are available, they should be compared to the bias and LOA estimates to assess if and by how much imprecision might account for the observed method differences.

Sometimes, the bias plot needs to be modified to account for more complicated relationships between method means and differences. In cases where the magnitude of the method differences changes with the magnitude of the measurement means while the bias stays the same (often, differences increase with increasing measurement magnitude), Bland and Altman (1999) recommend a logarithmic (log) transformation of all measurements before constructing a bias plot and then calculating the bias and 95% LOA for the log-transformed data. Back-transformed, the bias is equal to the geometric mean ratio of method A divided by method B measurements, and the 95% LOA represent a reference interval containing 95% of all method ratios. This type of bias plot is also called “ratio” plot and Figures 4b and 5b show examples of such plots. Finally, if both the method differences and the bias change over the range of measurements, Bland and Altman (1999) recommend a linear regression approach to calculating bias and 95% LOA (see Figures 6 b and 7 b).



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## Specific-Conductance, Water-Temperature, and Water-Level Data, San Francisco Bay, California, Water Years 2001-2002

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### Introduction

This article presents time-series plots of specific-conductance, water-temperature, and water-level data collected in San Francisco Bay during water years 2001 and 2002 (October 1, 2000, through September 30, 2002). Specific-conductance and water-temperature data were recorded at 15-minute intervals at the following US Geological Survey (USGS) locations (Figure 1):

- Suisun Bay at Benicia Bridge, near Benicia, California (BEN) (site # 11455780)
- Carquinez Strait at Carquinez Bridge, near Crockett, California (CARQ) (site # 11455820)
- Napa River at Mare Island Causeway, near Vallejo, California (NAP) (site # 11458370)
- San Pablo Strait at Point San Pablo, California (PSP) (site # 11181360)
- San Pablo Bay at Petaluma River Channel Marker 9, California (SPB) (site # 380519122262901)
- San Francisco Bay at Presidio Military Reservation, California (PRES) (site # 11162690)
- San Francisco Bay at Pier 24, at San Francisco, California (P24) (site # 11162700)
- San Francisco Bay at San Mateo Bridge, near Foster City, California (SMB) (site # 11162765).

Water-level data were recorded only at PSP through January 1, 2001. Suspended-sediment concentration data also were collected at most of these sites and were published by Buchanan and Ganju (2003).

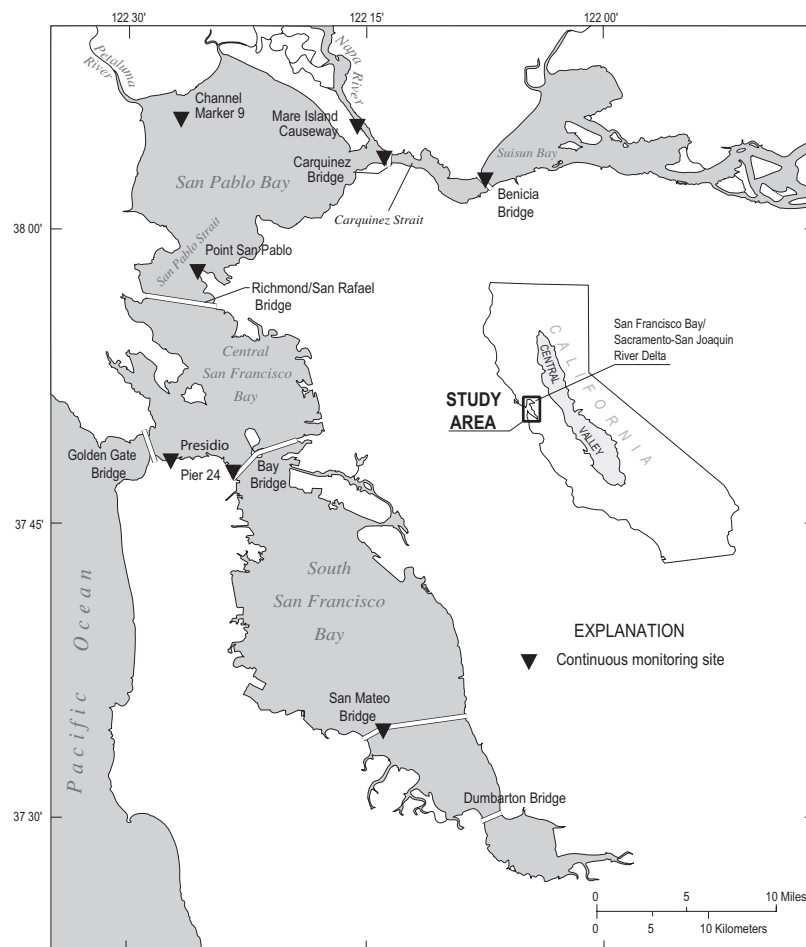
The data from PSP, PRES, P24, and SMB were recorded by the California Department of Water Resources (DWR) before 1988, by the USGS National Research Program from 1988 to 1989, and by the USGS-DWR cooperative program since 1990. BEN, CARQ, NAP, and SPB were established in 1998 by the USGS.

### Data Collection

Specific-conductance and water-temperature data were collected at near-surface and near-bottom depths in the water column to help determine the vertical stratification. However, at the more shallow San Pablo Bay and Presidio sites, data were collected only at near-bottom depth because the mean lower-low water depth<sup>1</sup> was about 6 feet.

Several types of instrumentation were used to measure specific-conductance and water-temperature data in San Francisco Bay. Instrument selection was site specific and was based on the availability of alternating current power at the site. Specific conductance [reported in microsiemens per centimeter at 25 ×Celsius (C)] was measured using either a Foxboro<sup>2</sup> electrochemical analyzer (calibrated accuracy ± 5%) or a Hydrolab Datasonde 4 multiprobe (conductivity cell calibrated accuracy ± 3%). Water temperature (reported in degrees Celsius) was measured using a Campbell Scientific thermister (accuracy ± 0.2 ×C) or the Hydrolab Datasonde 4 multiprobe (temperature probe accuracy ± 0.2 ×C). Water level (reported in feet) was measured using a Handar incremental encoder with a float-driven, incremental stainless-steel tape. Specific-conductance, water-temperature, and water-level measurements were recorded every 15 minutes.<sup>3</sup>

- 
1. The mean lower-low water depth is the average of the lower-low water height of each tidal day observed during the National Tidal Datum Epoch (NTDE). The NTDE is the specific 19-year period (1960-1978 for values given in this report) adopted by the National Ocean Service as the official time segment during which tidal observations are made and reduced to obtain mean values (Hicks, 1983).
  2. The use of firm, trade, and brand names in this report is for identification purposes only and does not constitute endorsement by the US Geological Survey or California Department of Water Resources.
  3. Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).



**Figure 1 Location of water-level, specific-conductance, and water-temperature data monitoring sites in San Francisco Bay, California**

Monitoring instrument calibrations were checked every 2-3 weeks. Calibration of the Foxboro specific-conductance instrument was checked using an Orion model 140 conductivity meter (calibrated accuracy  $\pm 2\%$ ) which was calibrated to a known specific-conductance standard (direct checks against a known standard are not possible with the Foxboro large-bore probe because of the large volume of standard needed). Calibration of the Hydrolab specific-conductance instrument was checked using a range of known specific-conductance standards. Calibration of the water-temperature instruments were checked using a VWR Scientific thermister (accuracy  $\pm 0.2^\circ\text{C}$ ). Water-level instruments were checked using a wire-weight gage mounted to the pier at Point San Pablo. Data corrections (normally resulting from biological fouling or instrument drift), based on differences between the monitoring instrument readings and the field-calibrated instrument readings taken before and after cleaning, were

applied to the record following the guidelines described by Wagner and others (2000).

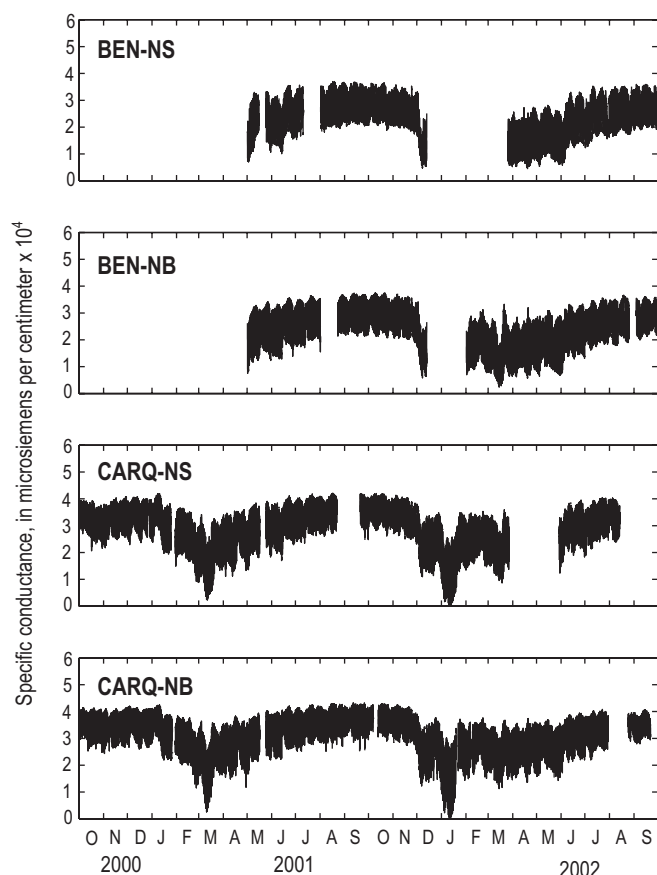
The monitoring site at Point San Pablo was discontinued on January 1, 2001, but reestablished December 12, 2001, using different instrumentation and deployment method. The water-level data collected after the Point San Pablo site was reestablished was not referenced to a point of known elevation (Bench Mark) and was not published. The San Mateo Bridge upper conductivity recorder was not operational from October 1 through November 15, 2000. The monitoring site at Pier 24 was discontinued on January 2, 2002.

### Data Presentation

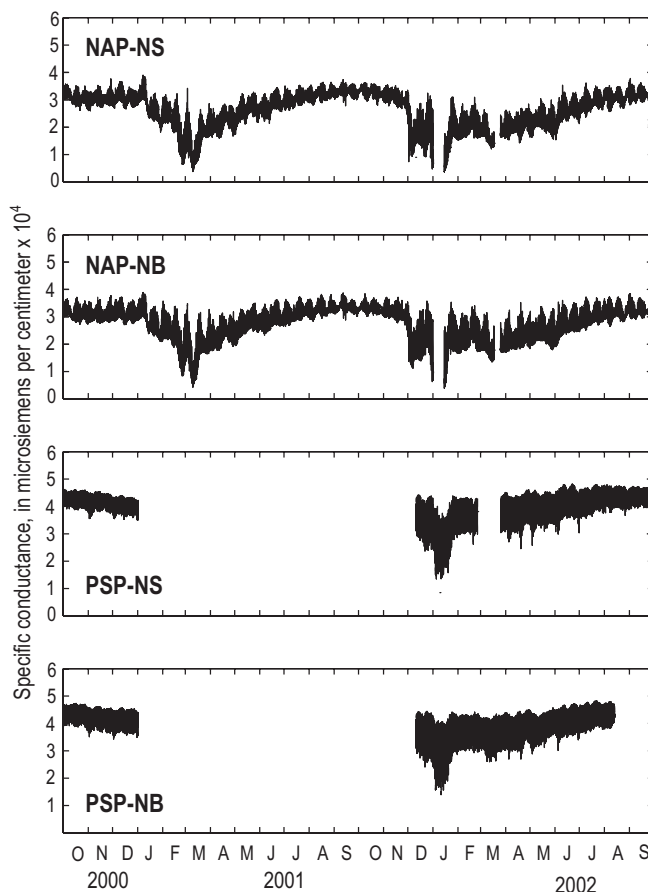
Figures 2 through 9 show time-series plots of the specific-conductance and water-temperature data measured at the eight sites in San Francisco Bay. Water-level data

measured at Point San Pablo is shown in Figure 10. Gaps in the data are caused primarily by equipment malfunctions and fouling. Tidal variability (ebb and flood) affects water level, specific conductance, and water temperature (Cloern and others 1989; Ruhl and Schoellhamer 2001). Tidal variability was greater in San Pablo Bay than in South San Francisco Bay (Schoellhamer 1997). To illustrate tidal variability, Figure 11 shows the near-surface and near-bottom specific conductance and water level at Point San Pablo for the 24 hours of October 1, 2000.

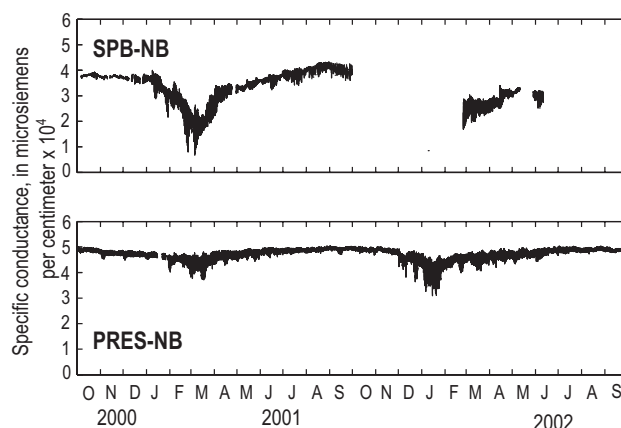
Maximum and minimum values of specific-conductance, water-temperature, and water-level data for the eight sites are published annually in Volume 2 of the USGS California water data report series, which is available on the USGS website (USGS, accessed August 12, 2003). The complete data sets are also available (USGS, accessed August 13, 2003).



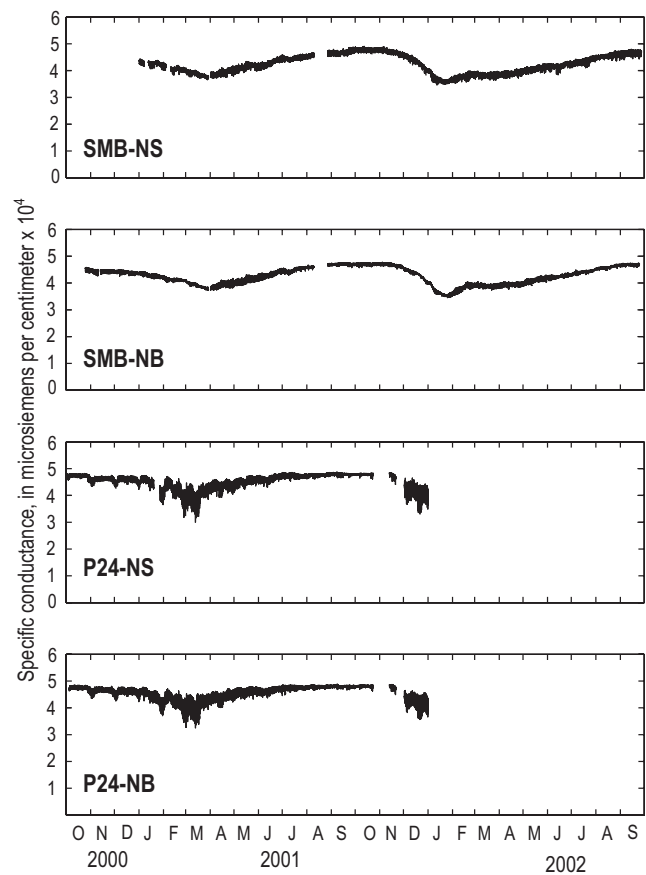
**Figure 2** Near-surface (NS) and near-bottom (NB) measurements of specific conductance at Benicia Bridge (BEN), and Carquinez Bridge (CARQ), San Francisco Bay, water years 2001 and 2002. For reference, seawater has a specific conductance of about 53,000 microsiemens per centimeter ( $5.3 \times 10^4$ )



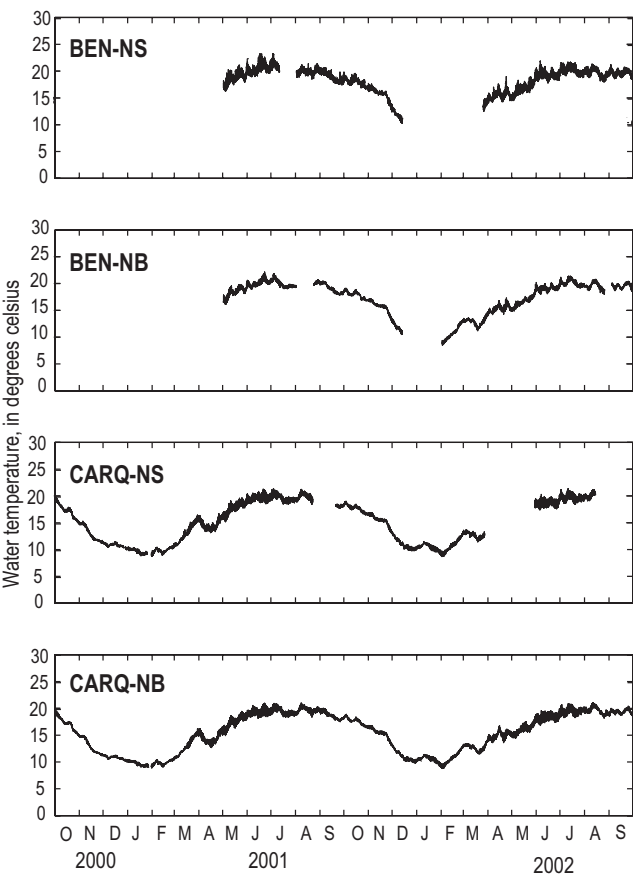
**Figure 3** Near-surface (NS) and near-bottom (NB) measurements of specific conductance at Napa River (NAP), and Point San Pablo (PSP), San Francisco Bay, water years 2001 and 2002. For reference, seawater has a specific conductance of about 53,000 microsiemens per centimeter ( $5.3 \times 10^4$ )



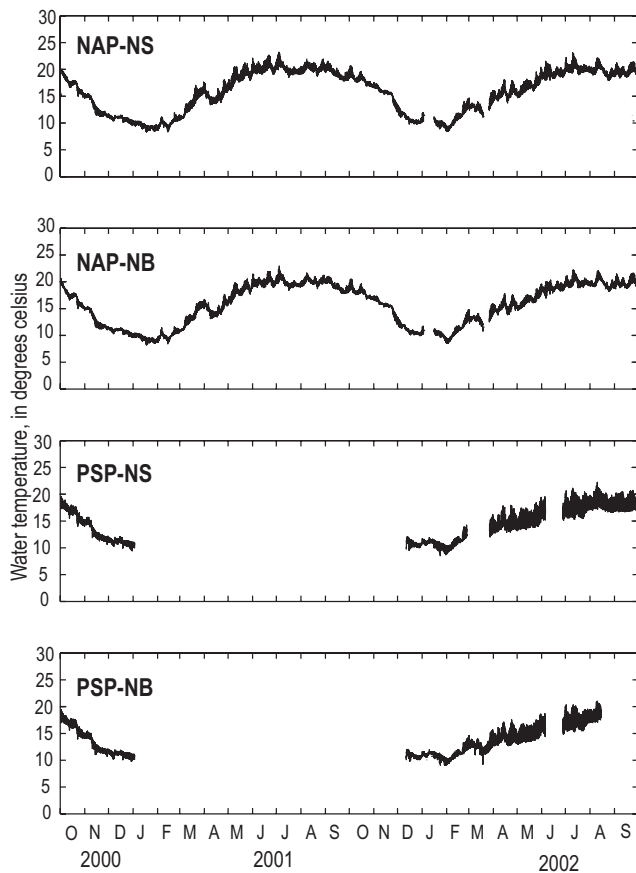
**Figure 4** Near-bottom (NB) measurements of specific conductance at San Pablo Bay (SPB), and Presidio (PRES), San Francisco Bay, water years 2001 and 2002. For reference, seawater has a specific conductance of about 53,000 microsiemens per centimeter ( $5.3 \times 10^4$ )



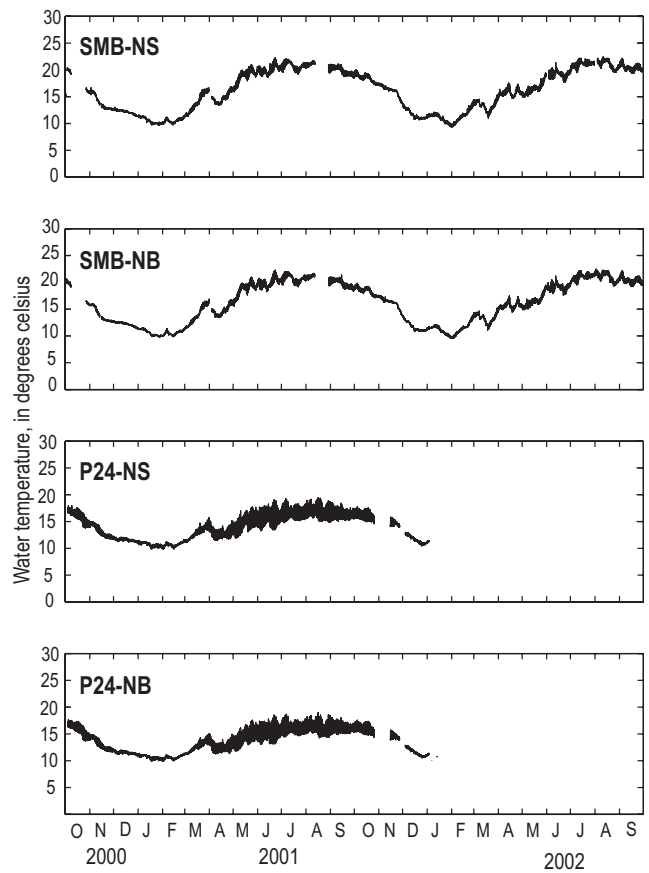
**Figure 5** Near-surface (NS) and near-bottom (NB) measurements of specific conductance at San Mateo Bridge (SMB), and Pier 24 (P24), San Francisco Bay, water years 2001 and 2002. For reference, seawater has a specific conductance of about 53,000 microsiemens per centimeter ( $5.3 \times 10^4$ )



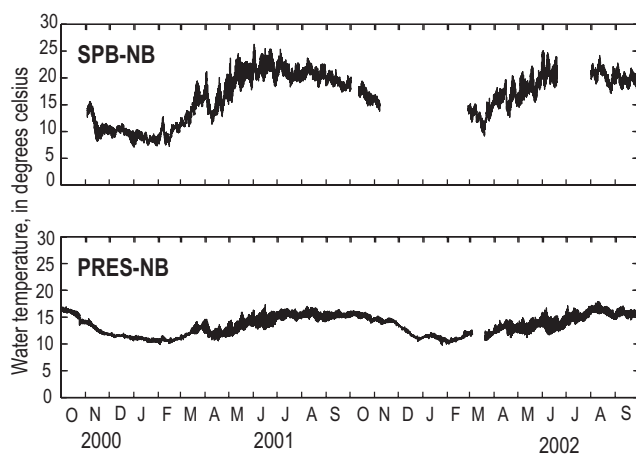
**Figure 6** Near-surface (NS) and near-bottom (NB) measurements of water temperature at Benicia Bridge (BEN), and Carquinez Bridge (CARQ), San Francisco Bay, water years 2001 and 2002



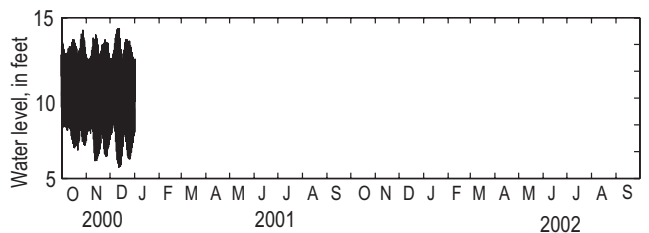
**Figure 7** Near-surface (NS) and near-bottom (NB) measurements of water temperature at Napa River (NAP), and Point San Pablo (PSP), San Francisco Bay, water years 2001 and 2002



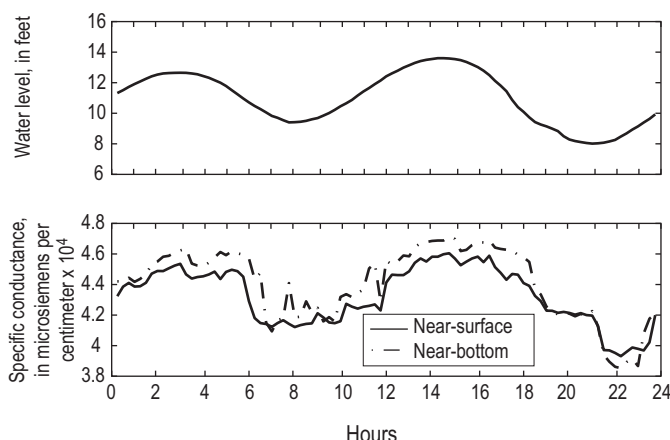
**Figure 9** Near-surface (NS) and near-bottom (NB) measurements of water temperature at San Mateo Bridge (SMB), and Pier 24 (P24), San Francisco Bay, water years 2001 and 2002



**Figure 8** Near-bottom (NB) measurements of water temperature at San Pablo Bay (SPB), and Presidio (PRES), San Francisco Bay, water years 2001 and 2002



**Figure 10** Water levels at Point San Pablo, San Francisco Bay, water years 2001 and 2002. Vertical datum is 10 feet below sea level (NGVD 29)



**Figure 11 Near-surface and near-bottom measurements of specific conductance and water levels at Point San Pablo, San Francisco Bay, October 1, 2000. Vertical datum is 10 feet below sea level (NGVD 29). For reference, seawater has a specific conductance of about 53,000 microsiemens per centimeter ( $5.3 \times 10^4$ )**

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## Dissolved Oxygen and Flow in the Stockton Ship Channel, Fall 2002

*Philip Giovannini, James C. Giulianotti, and Stephen P. Hayes (DWR), [pgiovann@water.ca.gov](mailto:pgiovann@water.ca.gov)*

Historically, during the late summer and early fall, dissolved oxygen (DO) levels in the eastern and central portions of the Stockton Ship Channel have dropped below both the 5.0 mg/L and 6.0 mg/L water quality objectives set by the State Water Resource Control Board and the Regional Water Quality Control Board, respectively. These low DO levels are a result of several factors, which include low San Joaquin River inflows, warm water temperatures, high biochemical oxygen demand, reduced tidal circulation, and intermittent reverse flow conditions in the San Joaquin River past Stockton.

Low DO levels have the potential to cause physiological stress to fish and block upstream migration of salmon. Therefore, in an effort to prevent these low DO conditions from occurring, the Department of Water Resources (DWR) normally installs a temporary rock barrier (Barrier) across the head of Old River during periods of projected low fall flows in the San Joaquin River. The Barrier increases net flows in the San Joaquin River past Stockton by eliminating upstream diversion of flows from the main river down Old River to Clifton Court Forebay.

Water year 2002<sup>1</sup> for the San Joaquin Valley<sup>2</sup> was classified as dry, with relatively low San Joaquin River daily flows measured at Vernalis ranging from 1,000 to 1,326 cfs during August and September. Because these low, late summer flows were not projected to be sufficient to alleviate DO concerns within the Eastern Channel, the Barrier was installed on October 4 and was in place until November 15. During the period in which the Barrier was in place, DO levels were generally high in all channel regions.

## Methods

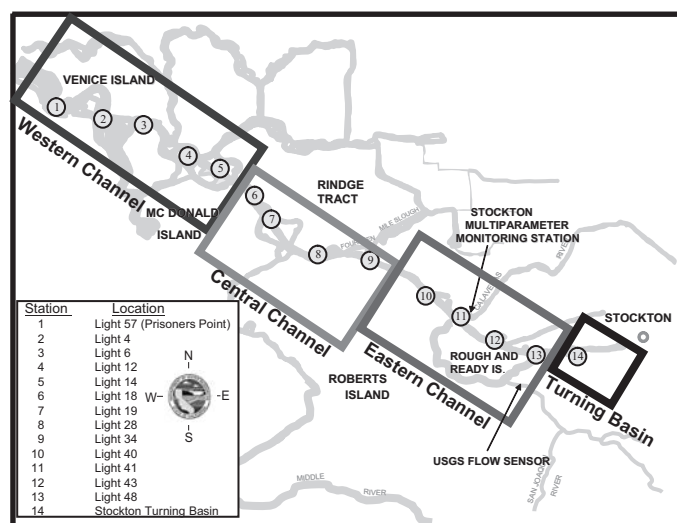
Monitoring of DO concentrations in the Stockton Ship Channel was conducted by vessel on nine monitoring runs from July 23 to December 18, 2002<sup>3</sup>. During each of the monitoring runs, 14 sites were sampled at low water slack, beginning at Prisoner's Point (Station 1) in the central Delta and ending at the Stockton Turning Basin at the terminus of the Ship Channel (Station 14).

Because monitoring results differ along the Channel<sup>4</sup>, for the purpose of this study, sampling stations are grouped into western, central, and eastern regions within the Channel (Figure 1). The Western Channel begins at Prisoner's Point (Station 1) and ends at Light 14 (Station 5). The Central Channel begins at Light 18 (Station 6) and ends at Light 34 (Station 9). Finally, the Eastern Channel begins at Light 40 (Station 10) and ends at Light 48 (Station 13). The Turning Basin (Station 14) is unique within the Channel because it is east of the entry

point of the San Joaquin River into the Channel and isolated from down-channel flow.

Discrete samples were taken from the top (1 meter from surface) and bottom (1 meter from bottom) of the water column at each station at low water slack, and analyzed for DO concentrations and temperature. DO levels measured below either state objective (5.0-6.0 mg/L) were classified as low. Flow data for the San Joaquin River at Vernalis and Stockton were obtained from continuous monitoring stations and compiled by DWR and USGS<sup>5</sup>.

Flow rates in the San Joaquin River at Stockton are heavily influenced by tidal action, with daily ebb and flood tidal flows of 3,000 cfs or greater in either direction. To calculate net daily flows, the tidal pulse is removed from the USGS 15-minute flow data with a Butterworth filter<sup>6</sup> to yield net daily flow. Because of low flows at Vernalis, local agricultural diversions, and export pumping, net daily flows at Stockton can sometimes reverse direction. However, net daily reverse flows at Stockton were not seen during the fall 2002 study period.



**Figure 1 Monitoring stations in the Stockton Ship Channel**

1. A water year is numbered using the calendar year in which the water year ends. Water Year 2002 extended from October 1, 2001 through September 30, 2002. Because Water Year 2002 ends mid-way through the August through November 2002 study period, the findings of the Fall 2002 Dissolved Oxygen Study are discussed primarily using the 2002 calendar year. This eliminates the need to use two water years to describe the one fall study period.
2. The San Joaquin Valley Water Year Index is used because inflows to the Stockton Ship Channel occur predominantly through the San Joaquin River. Because hydrologic conditions within the drainage basin of the San Joaquin River influence inflows to the Stockton Ship Channel, Water Year 2002 is used when discussing these conditions.
3. Funding for these special studies was provided by the Division of Operations and Maintenance, DWR
4. The findings of previous fall studies have shown that fall DO levels are typically: robust and high (7.0-9.0 mg/L) in the western Channel; transitional, variable (4.0-7.0 mg/L), and stratified in the central Channel; and low (3.0-5.0 mg/L) and stratified in the eastern Channel.

5. Station information: DWR Station SJR at Vernalis, RSAN112; USGS 304810 SJR at Stockton, RSAN063.
6. The USGS uses a Butterworth bandpass filter to remove frequencies (tidal cycles) from 15-minute flow data, that occur on less than a 30-hour period. The resulting 15-minute time-series is then averaged to provide a single daily value which represents net river flow exclusive of tidal cycles.



## Results and Discussion

During this study, DO levels varied considerably between regions within the Channel. DO concentrations in the Western Channel were relatively high and stable and ranged from 7.0 to 10.0 mg/L during the July 23 to December 18 study. The robustness of DO concentrations in this portion of the Channel was apparently due to the greater tidal mixing, the absence of conditions creating biochemical oxygen demand (BOD), and shorter hydrological residence time as compared to upstream regions.

Low DO conditions occurred in both the Central and Eastern Channel regions. These low DO conditions in the Central Channel appeared to be either extensions of low DO regions in the Eastern Channel, or as a result of low DO waters moving downstream from the eastern channel as inflows increased. In the Central Channel, DO concentrations dropped below 5.0 mg/L through much of September and October.

In the Eastern Channel, the DO levels were low in August and September, and stratified and more variable in October. DO levels ranged from a low of 3.3 mg/L in September to a high of 10.8 mg/L in October. Changing inflows from the San Joaquin River into the Eastern Channel may partially account for the variability of the DO levels within the Eastern Channel. Measured surface and bottom DO levels at 14 stations during 9 sampling runs conducted between July 23 and December 18 are shown in Figure 2.

Flows in the San Joaquin River past Vernalis remained fairly steady from July to mid-October ranging between 1,000 to 1,416 cfs (Figure 3). Flows increased in mid-October as a result of an early fall storm. Average daily flows past Vernalis in the second half of October peaked at 2,400 cfs. These improved October flows coincided with the installation of the Barrier at Old River on October 4. As a result, average net flows past Stockton increased markedly, ranging from 904 to 1,788 cfs during October.

DO levels showed significant improvement during this period. On October 7, only the Central Channel had DO levels below the 6 mg/L objective, and by October 22, DO levels in all portions of the Channel had risen above the 6 mg/L objective. Because of the improved DO conditions in the Central and Eastern Channels in late October and anticipated increases in fall San Joaquin River flows, the Barrier was removed on November 15.

The removal of the Barrier coincided with an immediate return of low DO conditions in the Eastern Channel (Figure 2). Average DO levels<sup>1</sup> in the East and East-Central Channel regions fell from a high of 8.6 mg/L pre-removal to 5.5 mg/L post-removal. The relationship between channel flow rates and average DO before, during, and after the installation of the Barrier is shown in Figure 3.

Decreased inflows to the Channel appear to have contributed to the return of low DO conditions within the eastern Channel in November. Net flows past Stockton were high in early November, but dropped dramatically from 1,687 cfs, to a low of 49 cfs one week after the removal of the Barrier. Although flows at Vernalis remained between 1,400 and 3,000 cfs for the remainder of the year, net flows past Stockton remained below 500 cfs, except for a brief pulse flow and moderate increase in mid-December.

The relatively low inflow conditions to the Channel continued through December with net daily San Joaquin River flow past Stockton ranging from 9 to 836 cfs, with a one-day pulse flow of 1,340 cfs occurring on December 17. On December 3, DO values in the Eastern Channel were exceptionally low, dropping to 3.3 mg/L at Station 11 (Figure 2). DO conditions in the Central Channel were similar to those in late November with low DO levels present only at Station 9.

Improved net San Joaquin River inflows past Stockton in late December and cooler water temperatures (11.3–12.8 °C) may have contributed to the slightly improved DO conditions measured in the Eastern Channel on December 18. Average DO levels in the East and East-Central Channel stations increased to 5.7 mg/L. Because of the improving conditions, the fall 2002 DO special study was terminated on December 18.

1. Average Channel DO values are calculated as the combined average of surface and bottom DO in the eastern and east central Channel regions (Stations 8 to 13) at the time of each monitoring run.



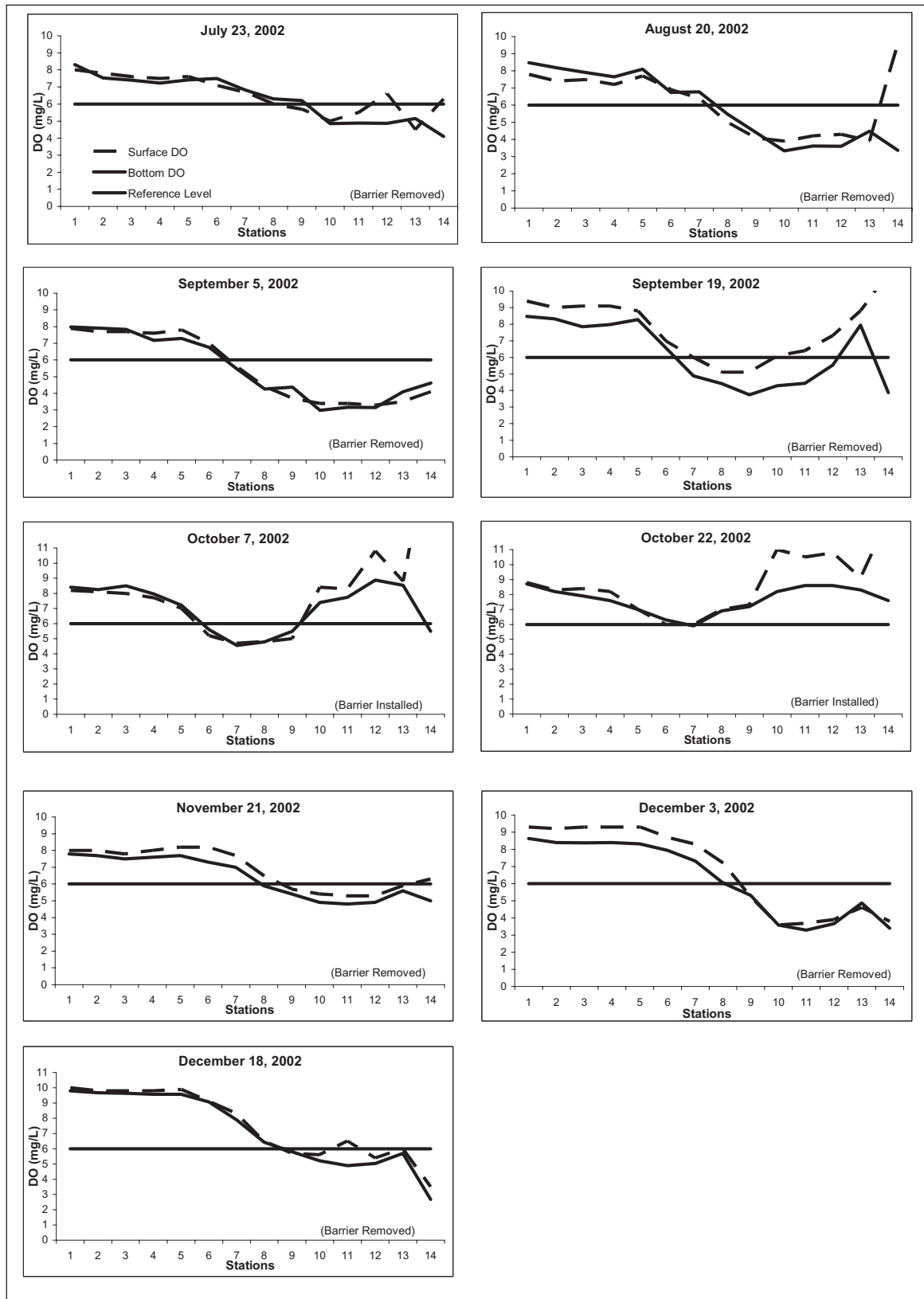


Figure 2 Fall 2002 dissolved oxygen concentrations in the Stockton Ship Channel

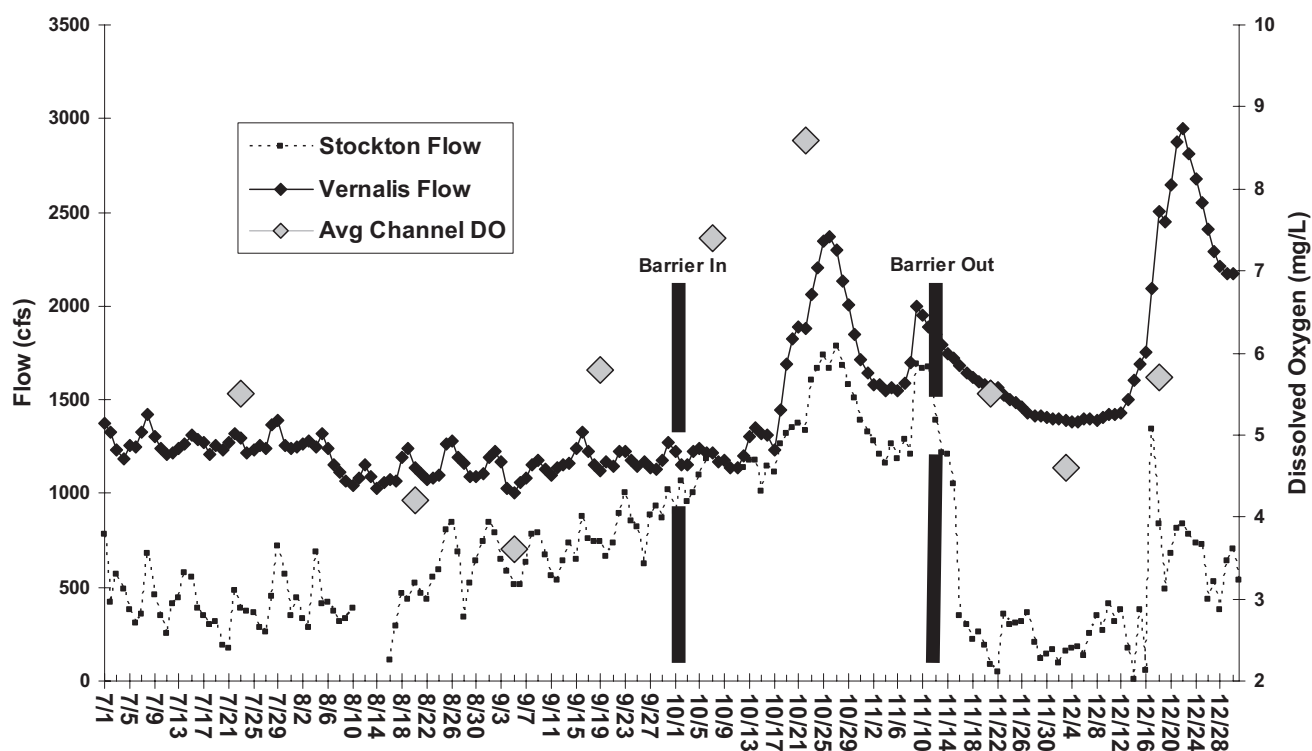


Figure 3 Flow conditions and average East and East-Central Channel DO levels, fall 2002

## Summary

Monitoring in the Stockton Ship Channel showed that DO levels consistently fell below the 5.0 mg/L and 6.0 mg/L objectives set by the State. Although the location of the low DO areas varied, eight of the nine monitoring runs conducted between July 23 and December 18, showed DO levels in the Channel below the 6.0 mg/L objective. In addition, average DO levels in the East and East-Central Channel regions were below the 6.0 mg/L objective in seven of the nine sampling runs. Both instances in which average DO levels in the East and East-Central Channel regions exceed 6.0 mg/L occurred during the period in which the Barrier was in place.

In previous years, DO levels throughout the Channel typically remained at greater than 6.0 mg/L within the Channel in late fall due to cooler water temperatures and improved inflows. In 2002, however, DO levels dropped below 6.0 mg/L in the Eastern Channel on November 21, and to less than 4.0 mg/L on December 3. The removal of the Barrier on November 15, during a period of high Delta exports or upstream diversions, markedly reduced net

flows past Stockton and apparently contributed to these low late-fall DO values within the Eastern Channel.

DO conditions improved slightly on December 18 with surface DO levels greater than 6.0 mg/L in much of the Eastern Channel, and bottom DO values in the Eastern Channel greater than 5.0 mg/L. Significantly cooler water temperatures, along with a moderate increase in net daily San Joaquin River flows past Stockton in December, appear to have ultimately contributed to sustained improvement of DO conditions in the Channel.

## 2003 Spring Kodiak Trawl

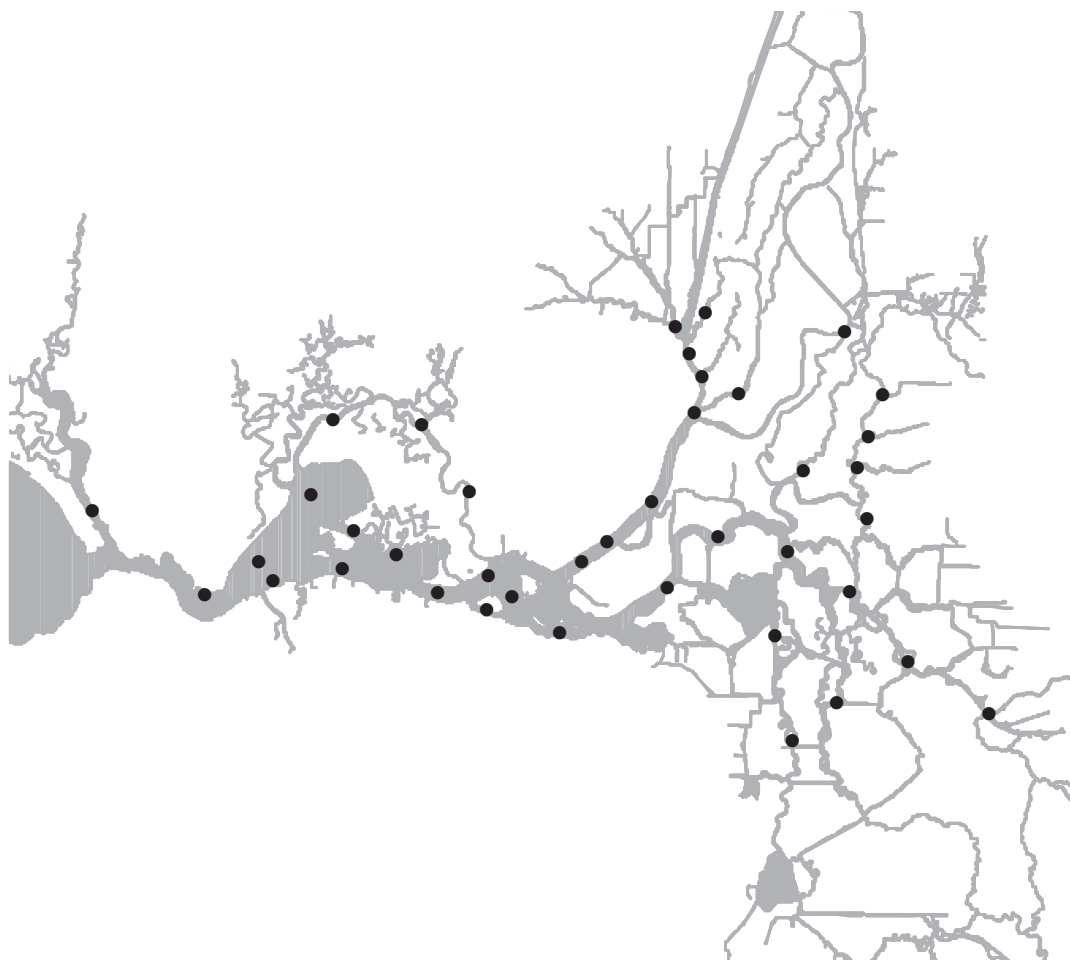
Kelly Souza (DFG), [ksouza@delta.dfg.ca.gov](mailto:ksouza@delta.dfg.ca.gov)

During spring 2003, the California Department of Fish and Game (DFG) completed 4 Delta-wide and 3 supplemental Kodiak trawl surveys designed to identify delta smelt (*Hypomesus transpacificus*) distribution and pro-

vide water managers and fisheries regulators with information on potential spawning distributions. This information is of particular interest when the distribution of Delta smelt favors the eastern or southern Delta, which usually precedes increased salvage (take) of adults and subsequent juveniles. The Delta-wide surveys (numbered consecutively beginning with 1) took 4 days to complete and sampled 39 stations extending from the Napa River to Walnut Grove on the Sacramento River, and to the city of Stockton on the San Joaquin River (Figure 1). Supplemental surveys (numbered consecutively beginning with 11) were intended to provide information about the progression of delta smelt maturity. They took 2 days to complete and were conducted in areas of greatest delta smelt density, as indicated by the catch data of the previous Delta-wide portion of the survey. Both the Delta-wide and supplemental surveys occurred once per month, beginning with a Delta-wide survey on 18 Feb 03, then alternat-

ing between sampling regimes every other week through early May.

Spring Kodiak trawl gear and gear deployment methods are described in Souza (2002). All fish caught were speciated, enumerated, and measured to the nearest millimeter fork length (FL) or total length (TL). Additional information collected for delta smelt included total volume of each fish (nearest mL), sex, and reproductive stage (Table 1). During supplemental surveys, heads were preserved in ethanol, small samples of eggs from stage 4 females were preserved in a 6:3:1 (formalin, ethanol, acetic acid) clearing agent, and the remaining body was preserved in 10% buffered formalin. These specimens are currently being archived; however, future research will include evaluations of hepatosomatic indices, fecundity, maturation, otoliths, gonad histology, and gonad histopathology.



**Figure 1** Locations of sampling stations for DFG's Delta-wide Spring Kodiak Trawl survey, Sacramento-San Joaquin Delta.

**Table 1 Macro-characteristics of male and female delta smelt (*Hypomesus transpacificus*) gonads used for determining reproductive maturity status of preserved specimens.**

Stage	Male	Female
I.	Left testis is barely visible and the right testis is impossible to find. Gonads < 0.1% of body weight.	Left ovary translucent and grainy in texture. Right ovary difficult to impossible to find.
II.	Testis visible as thin strands ventrolateral to the swim bladder. Gonads are less than 0.5% of body weight.	Looks the same as stage 1 when observed without a microscope.
III.	Right testis is visible as a small pale white or grey cord. Left testis has developed in the central portion of the gonadal cord.	Individual oocytes slightly orange, 0.25-0.50 mm in diameter, and visible to the naked eye.
IV.	Both testes are clearly visible, smooth, and pale white.	Abdomen is enlarged with egg mass and observable without dissection. Oocytes are bright orange and about 1 mm in diameter. Eggs can be stripped with gentle pressure.
V.	Testes are bright white and very smooth. Testes account for 2-4% of body weight. Milt can be released by gentle pressure.	Oocytes are larger than 1 mm in diameter, and hydrated. Clear fluid surrounds the orange oocytes that become increasingly cloudy and degenerate.
VI.	Testes and milt not as bright white as during stage V. During summer months, indicated by a decrease in size of testes.	Gonad is translucent and textured with a few leftover oocytes embedded in tissue. Loose abdomen easily detected.

Source: Adapted from personal communication (Mager 2001).

### Delta-wide surveys

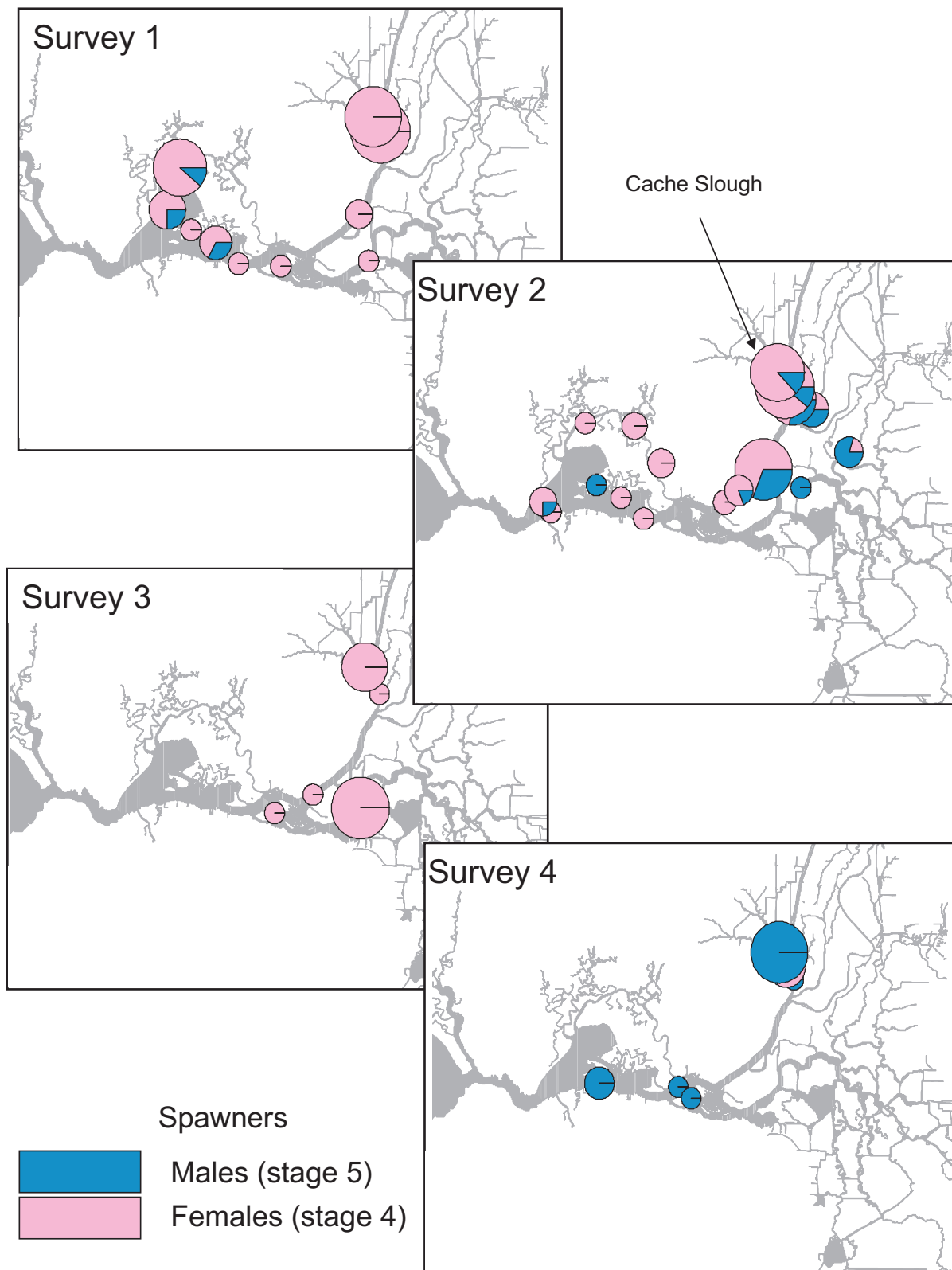
During the Delta-wide portion of the 2003 SKT, a total of 3,202 fishes representing 27 species and 14 families were collected. Three families comprised 89% of the total catch: Salmonidae (51%), Osmeridae (24%), and Clupeidae (14%). The most common fishes encountered were Chinook salmon (*Oncorhynchus tshawytscha*), followed by delta smelt, and threadfin shad (*Dorosoma petenense*). Large juvenile Chinook catches were likely due to hatchery releases that coincided with our sampling efforts.

Delta smelt were more widely distributed during survey 1 (18 Feb 03) and survey 2 (17 Mar 03) than during subsequent surveys. During this time, they were collected from the western-most area of Suisun Bay, within Montezuma Slough, through the confluence area, and inside of Cache Slough. During survey 1, smelt were also collected in the San Joaquin River, and during survey 2, smelt were collected as far north as Walnut Grove in the Sacramento River. With the exception of survey 3, stations in Cache Slough accounted for the majority of delta smelt catch (survey 1=56%, survey 2=49%, and survey 4=67%). This is different from distribution during 2002 when Montezuma Slough consistently had the largest concentration of delta smelt catch in all surveys (Souza 2002). This difference could be a result of the survey timing (which was deliberately delayed 6 weeks in 2003), rather than a function of environmental conditions. As the spawning season progressed, functionally mature delta smelt (stage 4 females and stage 5 males) distribution shifted from

Suisun Bay and the confluence area upstream to Cache Slough (Figure 2). Surveys 3 and 4 suggest that males appear to arrive later than females to spawning areas (Figure 2).

Distribution of spent fish (fish that have spawned) was limited during survey 1. Subsequent surveys had a larger range of spent smelt, including areas as far north as Walnut Grove on the Sacramento River (surveys 2 and 3), and in the North and South Mokelumne (survey 3) (Figure 3). The SKT has yet to detect spent fish in the Napa River (2002 or 2003), and very rarely are spent fish collected in Montezuma Slough (survey 2, Figure 3).

Environmental conditions at the time and location of capture for the majority of delta smelt collected consisted of water temperatures between 11 and 14 °C (94%) (Figure 4) and specific conductivities (corrected for 25 °C) ranging between 131 and 3,200 mS/cm (97%) (Figure 5). Delta smelt catch from the Delta-wide surveys were adjusted to account for the frequency of temperature and specific conductance readings so that more frequent readings were not overrepresented.



**Figure 2** Distribution of stage 5 males and stage 4 females (spawning) delta smelt (*Hypomesus transpacificus*) collected during the 2003 Spring Kodiak Trawl, Delta-wide surveys.

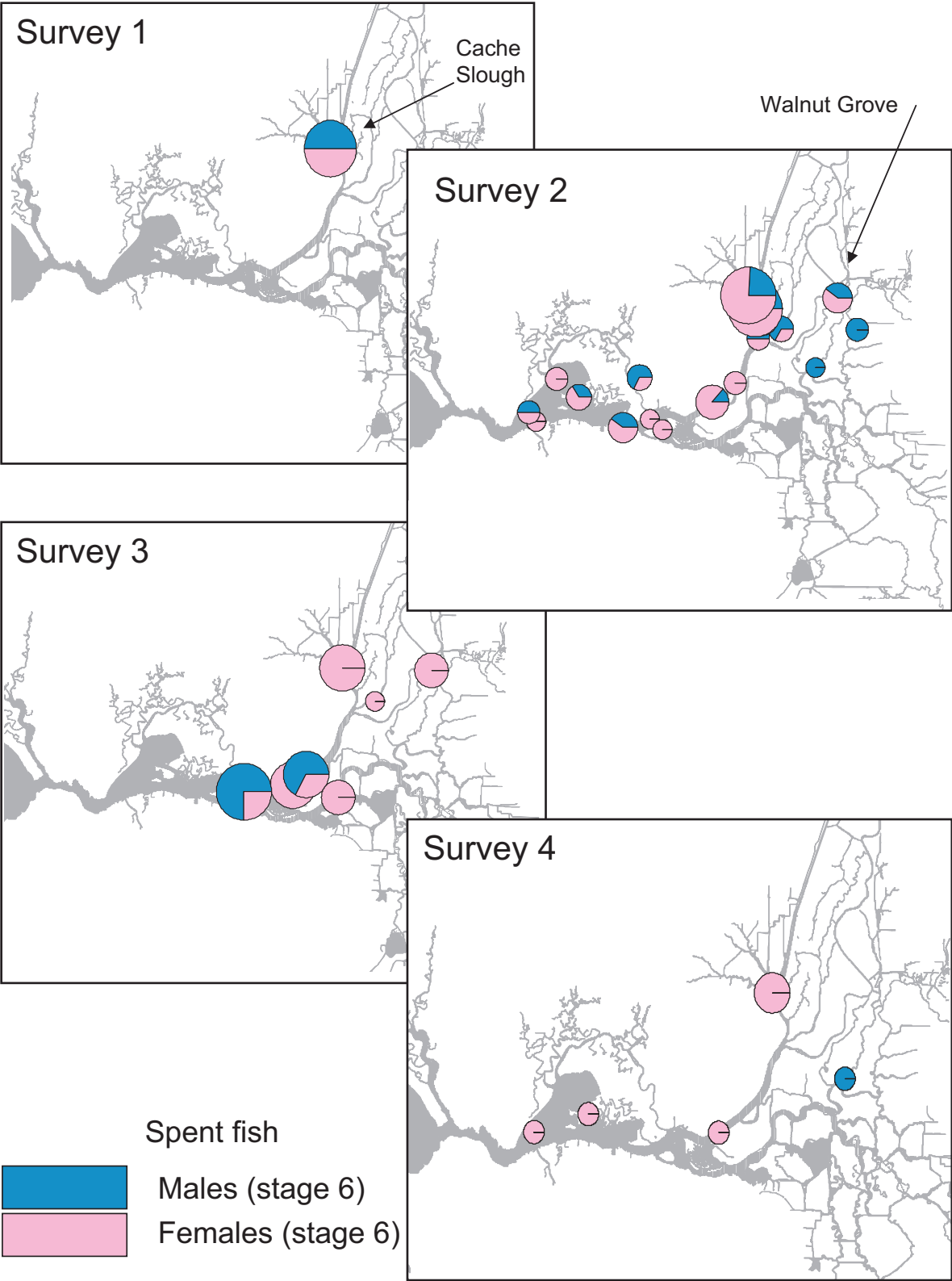
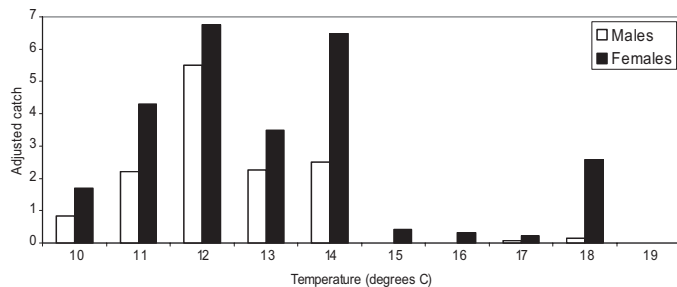
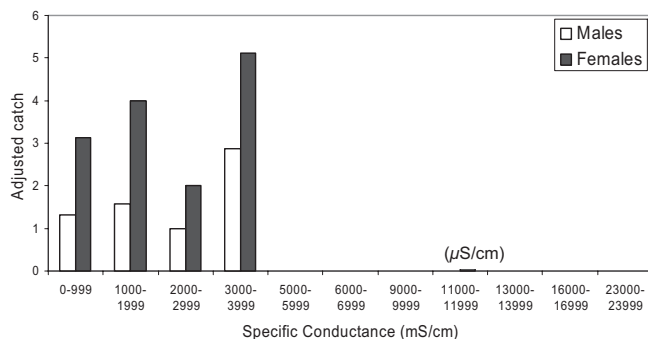


Figure 3 Distribution of stage 6 male and female (spent) delta smelt (*Hypomesus transpacificus*) collected during the 2003 Spring Kodiak Trawl, Delta-wide surveys.



**Figure 4** Male and female delta smelt catch adjusted for frequency of water temperature readings (°C), 2003 Spring Kodiak Trawl, Delta-wide surveys.



**Figure 5** Male and female delta smelt catch adjusted for frequency of specific conductance (mS/cm) readings, 2003 Spring Kodiak Trawl, Delta-wide surveys.

### Supplemental Surveys

Most of the supplemental surveys were conducted within the Sacramento Deep Water Channel (SDWC). Attempts were made to sample Honker Bay, Montezuma Slough, Nurse Slough, and the lower Sacramento River near Brannan Island, but sufficient numbers of fish were not collected in those areas to warrant additional sampling. Consistently low catches of delta smelt indicated that fish were further upstream so subsequent sampling was concentrated in the SDWC, where numerous delta smelt were consistently collected. Tows were made between lights 53 and 54 (approximately 1.7 miles above the confluence of Cache and Miner sloughs), throughout the SDWC adjacent to the Yolo Bypass Wildlife Area, and all the way to the Sacramento Turning Basin, past Lake Washington.

More delta smelt were collected in the SDWC during supplemental surveys (n=678) than during all 4 Delta-wide surveys (n=669). Males and females collected in this area were found to be predominately in stage 5 and 4, respectively (functionally mature), and stage 6 (spent).

The male to female sex ratio was constant (1:4) in all supplemental surveys, and, in Delta-wide surveys, the sex ratio was as great as 1:15 (Table 2). This is the same pattern that was observed in the 2002 SKT survey, during which the number of females collected gradually increased with the progression of the spawning season. It is not clear why this pattern exists, but possibilities include: (1) females may be more vulnerable to the sampling gear at this time, or (2) females persist longer after spawning.

More detailed maps of delta smelt reproductive maturity can be found at <http://www.delta.dfg.ca.gov/data/skt/>.

**Table 2** Male to female sex ratios of delta smelt caught during Delta-wide and Supplemental surveys of the Spring Kodiak Trawl, 2003.

Date	Survey	Males	Females	Total	M:F Sex ratio
Delta-wide surveys					
2/18-2/21	1	82	145	227	1:2
3/17-3/20	2	113	258	371	1:2
4/14-4/17	3	8	35	43	1:4
5/13-5/16	4	2	29	31	1:15
Supplemental surveys					
3/3-3/4	11	55	195	250	1:4
4/2-4/4	12	34	124	158	1:4
4/28-5/2	13	72	269	341	1:4
Total		366	1,055	1,421	1:3

### References

Souza K. 2002. Revision of California Department of Fish and Game's Spring Midwater Trawl and Results of the 2002 Spring Kodiak Trawl. IEP Newsletter 15(3):44-7.

### Notes

Mager RC. (Department of Water Resources). 14 June 2002. E-mail communication.

## Use of a Portable Resistance Board Weir to Count and Characterize Runs of Anadromous Salmonids in the Stanislaus River

Doug Demko, Michele Simpson, and Chrissy Sonke (S.P. Cramer & Associates, Inc.), [demko@spcramer.com](mailto:demko@spcramer.com)

### Introduction

Adult Chinook salmon (*Oncorhynchus tshawytscha*) escapement in most Central Valley tributaries is currently determined using conventional carcass mark-recapture methods (Boydston 1994; Law 1994). Carcass-based abundance estimates require a series of underlying assumptions regarding random distribution of tagged carcasses and tag recovery effort, carcass visibility, and tag retention. Assumptions are largely untested but can substantially affect the accuracy of abundance estimates (Ricker 1975; Seber 1982; Cavallo 2000). In addition, carcass surveys are not suitable for enumerating spawning steelhead (*O. mykiss*) since most do not die after spawning. Steelhead enumeration is made even more difficult by high flows and turbidity typically associated with their upstream migration and spawning periods, which makes visual observations often impossible. Accurate estimates of adult salmon and steelhead escapement are key to valid assessments of stock status and to developing effective protection or recovery efforts for each species.

Portable resistance board weirs (a.k.a., Alaskan weirs) are an alternative to carcass surveys that can provide direct, reliable counts of adult salmon, and are perhaps the only method that can successfully enumerate adult steelhead. These weirs are currently used by state and federal agencies in Alaska and are widely accepted to be an effective and efficient method of enumerating upstream migrants, even during periods of substantial flow fluctuations and debris loading. Alaskan weirs have not been previously evaluated in the Central Valley due to potential factors, such as the reluctance to consider new methods of estimating escapement due to the long time-series of data that currently exists for Chinook carcass surveys, and the mistaken belief that all weirs are rigid objects which do not function well under fluctuating flows, and can not be operated in navigable waterways. Alaskan weirs are a relatively new alternative to other

weirs which have the advantages of being able to consistently provide reliable information in streams with fluctuating flows and high debris loads, are easily portable, and are able to incorporate boat passage facilities within them. They are typically used in streams that experience debris-laden high water periods (Tobin 1994), since they temporarily submerge under pressure created by debris loading which allows debris to pass before reaching a critical mass that would damage a traditional weir. The ability to submerge under pressure also facilitates passage of watercraft moving downstream.

Another relatively new technology that may be used in conjunction with Alaskan weirs for fish passage monitoring is a combined infrared and digital camera system known as the Vaki RiverWatcher (Vaki) manufactured in Iceland by Vaki ([www.vaki.is](http://www.vaki.is)). The Vaki is gaining popularity with fisheries researchers as a way to remotely identify and enumerate salmonids in free-flowing streams and can potentially be used as a non-invasive way of sampling special status and Endangered Species Act listed species. In California, Vaki RiverWatcher systems have recently been installed and are being used to monitor salmonid escapement on three rivers. Although this technology is rapidly spreading on the West Coast, there are currently no published evaluations of its accuracy or limitations, but unpublished accounts indicate managers are capable of reliably determining species, length, and gender with infrared and digital photograph images provided by the Vaki system.

### Project Overview

A demonstration Alaskan weir project was proposed for implementation on the Stanislaus River by Tri-Dam Project, Oakdale Irrigation District, and South San Joaquin Irrigation District, and selected for funding by the Anadromous Fish Restoration Program (AFRP) during the 2002 CALFED proposal solicitation process. This three year test of an Alaskan weir began in late fall of 2002 and was designed to demonstrate the practicality of using an Alaskan weir to: (1) estimate Chinook salmon and steelhead escapement in the Stanislaus River and compare this estimation method with traditional Chinook carcass survey estimates in the Stanislaus River and in other Central Valley tributaries, (2) collect biological data on adult Chinook salmon and steelhead upstream migrants that could not previously be collected using other methods, and (3) determine the precision of the Vaki at estimating adult Chinook and steelhead abundance and providing information on fish lengths, gender, and pres-



ence/absence of adipose fins without direct handling of individual fish.

Direct counts (a combination of visual observation, trapping, and infrared and digital images) of fall-run Chinook salmon obtained at the weir will be used to estimate Chinook escapement and will be compared with Chinook carcass survey estimates in the Stanislaus River to evaluate the differences between the two methods. In addition, it is anticipated that the operation of the weir, in conjunction with the Vaki, will provide us, for the first time in the Central Valley, with a means of effectively enumerating natural steelhead during their upstream spawning migration and will allow us to answer questions regarding their abundance and migration characteristics.

As part of our evaluation, we plan to conduct several short-duration trapping tests concurrently with operation of the Vaki system, then compare the trapping results with infrared and digital camera images to calibrate and test the ability of the Vaki system to enumerate and measure salmonids. Although the system automatically counts and estimates lengths of each fish, each image (either infrared during high turbidity or digital photograph during high visibility) must be reviewed to identify species, gender, and presence/absence of an adipose fin. Although analyzing scales is not part of our study, some scales are being collected and provided to California Department of Fish

and Game, which can be analyzed in the future to provide valuable information on life-history including age, freshwater versus ocean residence time, and genetic origin.

### Weir Description

The Stanislaus River weir was designed based on resistance board weirs used in Alaska. The weir consists of an array of rectangular panels (20 feet long by 3 feet wide) that are made of evenly spaced, 20 foot long, polyvinyl chloride electrical conduit pickets (1-inch schedule 40 PVC) that are aligned parallel to the direction of stream flow. The upstream end of each panel is hinged to a substrate rail that is anchored to the stream bottom while the downstream end is held at the water surface by a buoyant resistance board that planes upward in flowing water (Figure 1). When the panels are installed, the barrier inhibits upstream adult salmonid migration while allowing water and objects (for example, debris and watercraft) moving downstream to easily pass. Fish encountering the weir can only continue traveling upstream past the structure through a designated opening known as the passing chute which directs fish past the Vaki system into a livebox. Although fish will typically continue migrating upstream unhindered through the livebox, there will be short periods when the livebox is closed at the upstream end to temporarily trap fish for biological sampling.

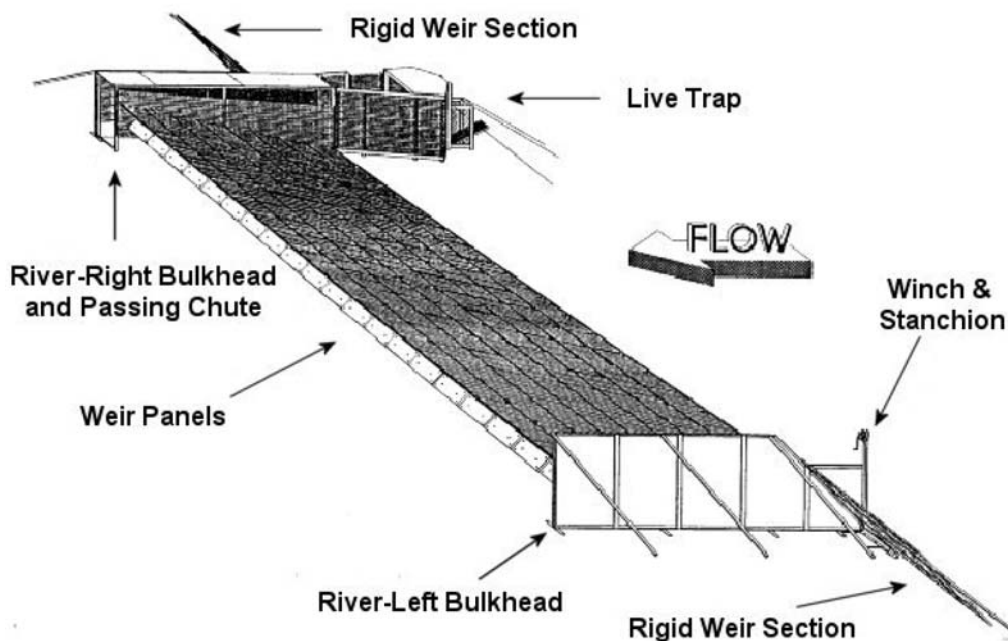


Figure 1 Example of a resistance board weir used by the USFWS in Alaska. (Diagram reproduced from Tobin 1994.)

On occasions when fish are trapped and processed, handling stress is minimized by several design features incorporated from other weir projects. Additional features were built-in into the livebox that are specific to our intended use, such as the livebox being significantly oversized to reduce fish crowding to the greatest extent possible. An internal dividing rack was also included which can, in effect, create two liveboxes; the front one to contain fish entering the apparatus and the rear one to process them. Each of the compartments is adjustable to any size, but as one gets larger the other gets smaller, so it doubles as a crowding device. Fish can be quickly transferred between capture (front) and processing (rear) without being lifted very far out of water since the height of the divider is adjustable and can be near or underwater.

Since the Stanislaus River is classified as a navigable waterway by the US Army Corps of Engineers and is used by rafters, swimmers, and boaters, we designed the weir to safely permit objects (for example, watercraft, river debris, swimmers, etc.) floating downstream and boats moving upstream to pass over the structure unimpeded. A portion of two of the weir panels on the downstream side of the weir was modified to accommodate boat passage. This boat passage section consists of PVC pickets that are aligned perpendicular to both the flow and adjacent weir pickets, and are tied together with three stringers in such a way that the downstream edge of this section is elevated slightly out of the water in its resting position and automatically submerges when contacted by a watercraft. Signs stationed above and below the weir instruct boaters to pass over the weir at this boat passage section, which is designated by a line of buoys and lights placed on each side of the passage entrance, both upstream and downstream of the weir.

## Results to Date

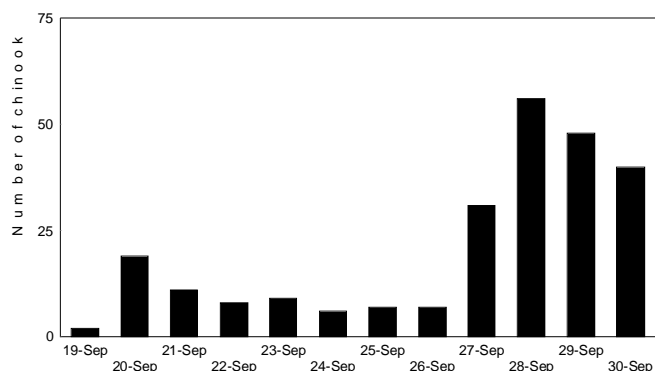
In February 2003, we installed the weir and conducted performance testing for approximately three months to determine whether the original weir configuration functioned as designed and would hold in the sandy substrate of the lower Stanislaus River, or whether modifications were necessary. We were concerned that this sandy substrate might be susceptible to mobilization and cause the weir to shift, particularly due to its portable and compressible nature. We had found no examples, out of over 30 weirs researched, where a weir was placed in an area of stream with sand.

During performance testing, flows ranged from 275 cfs to 1,500 cfs. We determined that watercraft and

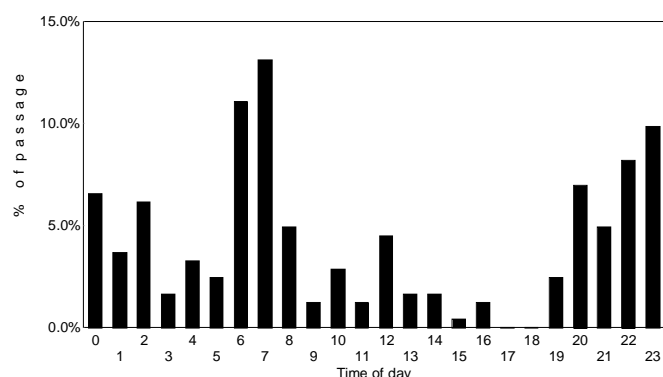
swimmers can easily pass the weir and that most pieces of large debris pass over the weir without assistance as designed. However, smaller pieces of floating debris, particularly elodea which impinges easily against the weir, must be removed mechanically on a daily basis. We also found that the substrate rail remains attached to the substrate and continues to hold the weir in place. Also, we observed some minimal scouring at the rigid weir panel on the south bank, but this problem was fixed and so far during 2003 sampling no scouring has been observed. The weir was removed for storage on April 28, 2003.

The weir was re-installed on September 5, 2003, and will continue to operate through April 30, 2004. On September 19, the Vaki system was installed and the first Chinook salmon was detected. As of September 30, a total of 244 adult Chinook salmon have been recorded (Figure 2). Based on the timing of initial fish observations and physical parameters monitored at the Rough and Ready Island (RRI; data available at [www.cdec.water.ca.gov](http://www.cdec.water.ca.gov)) station within the San Joaquin's deep water ship channel, the initial fall-run Chinook migration into the Stanislaus River this year appeared to coincide with a combined increase in DO to above 4 mg/L and a decrease in water temperatures to below 76 °F within the San Joaquin River. Changes in DO and temperatures at RRI began occurring several days preceding the first observations of Chinook within the Stanislaus River, with DO and water temperature ranging between 4.3 to 4.8 mg/L and 75.1 °F and 75.4 °F (9/12 to 9/16). As fish abundance increased at the weir between September 17 and 30, DO and temperatures continued to improve at RRI and they ranged between 5.4 to 7.0 mg/L and 72.1 °F and 74.4 °F. During the fall 2003 field sampling period, most fish passage at the weir occurred between 8 pm to 8 am with peak passage recorded just prior to sunrise, and another smaller peak just prior to midnight (Figure 3). A large percentage of fish were estimated to be between 650 and 800 mm in forklength (Figure 4) with approximately 15% categorized as grilse (<600 mm based on Mokelumne River grilse criteria).

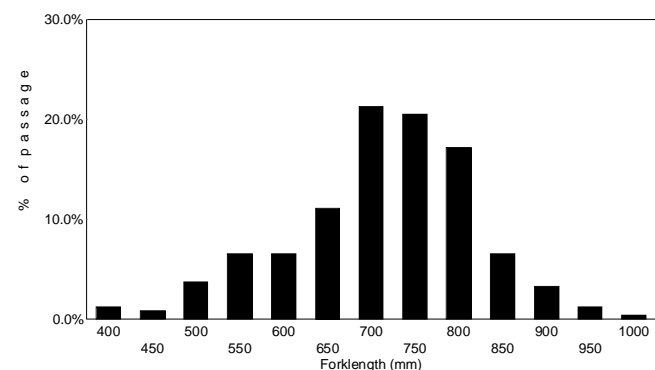
Due to elevated water temperatures at the weir site we have not trapped and handled fish, which means we have been unable to collect the biological sampling information needed for comparison with the Vaki images. When temperatures drop below 60 °F, we will begin periodically handling fish and conducting experiments to evaluate the ability of technicians to accurately determine biological characteristics from Vaki images, and the ability of the Vaki to automatically enumerate and estimate lengths of upstream migrating salmon and steelhead.



**Figure 2** Number of fall-run Chinook salmon adults recorded passing the Stanislaus River Weir by the Vaki RiverWatcher infrared camera from September 19 to September 30, 2003.



**Figure 3** Percentage of adult Chinook salmon (n=244) passing the Stanislaus River Weir during different times of the day ranging in one hour increments from 12 am (0) to 11 pm (23).



**Figure 4** Percentage of fall-run Chinook salmon (n=244) passing the Stanislaus River Weir within a given size class (forklength) ranging in increments of 50 mm from 400 to 1,000 mm.

## Reporting

This project was designed to be a demonstration project that would not only demonstrate the effectiveness of an Alaskan weir on the Stanislaus River, but would also provide resource managers with information that could be used to determine whether an Alaskan weir would be a viable management tool for other watersheds besides the Stanislaus River, particularly within the Central Valley. Therefore, we distribute a weekly newsletter with our sampling results via e-mail to interested parties, as well as on our website ([www.stanislausriver.com](http://www.stanislausriver.com)). In addition, our newsletter also includes information about the weir design and components that others can use to design and implement their own weir system. If you would like to follow this project on a real-time basis and be added to our e-mail distribution list, send an e-mail request to [demko@spramer.com](mailto:demko@spramer.com).

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# CALIFORNIA BAY- DELTA AUTHORITY ACTIVITIES

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## ***San Francisco Estuary and Watershed Science: An Electronic Forum on Science and Resource Management of San Francisco Bay, the Sacramento-San Joaquin River Delta, and the Upstream Watersheds***

*Lauren Buffaloe (CBDA), [buffaloe@water.ca.gov](mailto:buffaloe@water.ca.gov)*

A new online journal has been developed—*San Francisco Estuary and Watershed Science*—to provide an electronic forum on science and resource management of the San Francisco Bay, Sacramento-San Joaquin River Delta, and upstream watersheds. The new journal is a collaborative project of the California Digital Library; the California Bay-Delta Authority Science Program; the University of California, Davis' John Muir Institute for the Environment; and the San Francisco Bay-Delta Science Consortium. *San Francisco Estuary and Watershed Science* is an eScholarship Repository journal. The Repository (<http://repositories.cdlib.org/escholarship/>) is hosted by the California Digital Library (<http://www.cdlib.org/>). An initiative of the University of California, the CDL partners with UC campuses to apply innovative technology to managing scholarly communication.

*San Francisco Estuary and Watershed Science* will foster the communication of collaborative, peer-reviewed research by presenting original research findings, reviews, techniques, and comments to advance the current state of knowledge about the ecology of the San Francisco Bay-Delta region. The journal provides researchers who are concluding new information about the region with an outlet for sharing their work more readily with policy-makers who use the information for managing the region's natural resources. The journal's flexible online

medium and peer-reviewed format will accommodate a wide range of papers—from technical notes to monographs—to communicate both tightly focused individual studies and longer papers presenting detailed reviews.

The first issue of *San Francisco Estuary and Watershed Science* is available online (<http://repositories.cdlib.org/jmie/sfews>). Readers are encouraged to access this dynamic new forum for receiving relevant, high-quality science and regional researchers are encouraged to consider publishing in this new journal.

## **The 2004 CALFED Science Conference**

The 3<sup>rd</sup> Biennial CALFED Science Conference will be held from October 4 through 6, 2004, at the Sacramento Convention Center. The general conference theme is "Getting Results: Integrating Science and Management to Achieve System-Level Benefits". A call for abstracts will be circulated in early February 2004. Anyone wishing to organize a special session should contact the Program Chairs: Anke Mueller-Solger ([amueller@water.ca.gov](mailto:amueller@water.ca.gov)) or Dave Schoellhamer ([dschoell@usgs.gov](mailto:dschoell@usgs.gov)).

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# ON THE HORIZON

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## Peering into California's Water Future

On the surface coming up with a long-term water plan for a state as enormous and diverse as California seems not only daunting, but like an exercise in frustration. With the nation's most prolific agricultural sector, not to mention the world's fifth largest economy, California's water needs are immense. By the year 2030 California's population is expected to grow by more than 17 million. Add in other factors, like planning for uncertainties—such as droughts, potential climate change impacts, or catastrophic events—and coming up with a water plan that peers into the future becomes even more of a challenge.

Given these challenges how could the California Department of Water Resources (DWR), mandated by law to update its water plan every 5 years, come up with something “useful”? Defining the purpose of the California Water Plan Update (Update) was relatively easy: State policy- and decision-makers need a strategic water plan, planners need guidance for managing and developing California water, and there is the need for a framework for investing public funds. The hard part was figuring out how to approach it all.

Given the diverse opinions on water planning around the state, how do you take the concerns of passionate growers, environmentalists, tribal representatives, and rural and city planners all into consideration?

The answer? Put them all at the same table. It is a process called collaboration. Beginning in 2000, DWR set out on a new planning approach for the Update—a combination of strategic planning and strong public participation based on an open and transparent process seeking collaborative recommendations. This has resulted in substantial reformulation of the planning process used for development of the current edition of the Update. The approach also reflects the state's affirmation that the regions are the front line for planning.

The engine driving this approach continues to be the 65-member public Advisory Committee which meets reg-

ularly and is comprised of representatives from across the state. The Department also created the Extended Review Forum open to everyone to further invite input and share information through e-mails and public briefings.

The draft California Water Plan Update 2003 will be released at the end of 2003. Here's a brief summary of what you will find in the plan:

- Water Portfolios: estimates of water supplies and uses for recent years using actual data.
- Regional reports: descriptions of conditions, challenges, responses and planning efforts for the hydrologic regions in California (based on Senate Bill 672-Machado)
- Multiple scenarios: consideration of several plausible “futures” to account for uncertainties and risks (not single forecast)
- Diverse strategies: assessment of potential benefits, costs, implementation issues and solutions for two dozen resource management strategies (using the 3E's: economics, environment, equity)

Packed into four volumes, the Update aspires to be useful on multiple levels. Of course planning for the future is not a perfect science. Challenges the Advisory Committee has had to deal with include: significant data and information gaps; modeling tools not yet fully developed, documented or tested; and the need for significant resources and time to develop the new collaborative process and planning framework. Additionally, the State's budget crisis has reduced the Department's staff and budget for Water Plan activities. Still, with the input of hundreds of people from diverse communities the new planning framework is exciting many around the state. To see the draft as well as details and time lines for addressing the limitations go to the website: [www.Water-Plan.water.ca.gov](http://www.Water-Plan.water.ca.gov)

# RECENT RESEARCH PUBLISHED IN THE OPEN LITERATURE

*Compiled by Ted Sommer (DWR),  
tsommer@water.ca.gov*

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# DELTA WATER PROJECT OPERATIONS

*Kate Le (DWR), kle@water.ca.gov*

From July through September 2003, San Joaquin River flow ranged between 1,250 cfs and 2,280 cfs (35 and 65 m<sup>3</sup>/s), Sacramento flow ranged between 12,580 to 25,550 cfs (350 and 720 m<sup>3</sup>/s), and the Net Delta Outflow Index (NDOI) ranged between 2,000 and 14,000 cfs (60 and 400 m<sup>3</sup>/s as shown in Figure 1. Compared to last year's flow levels, Sacramento River and NDOI flows were much higher during the July through mid-August 2003 period. Thereafter, flow levels were similar to those in the same period last year. The largest peak in NDOI occurred at the end of July 2003, which was a result of releases to meet water quality standard at Jersey Point. The late August NDOI peak was a result of an 1,800 cfs runoff plus high Sacramento River flow. The San Joaquin River flow pattern was similar to that of the previous year, but at a slightly higher flow level.

Export action from July through September 2003 at the State Water Project (SWP) pumps was higher compared to last year's pumping during this time period. The significant changes in SWP pumping during July through September 2003 were made to meet either outflow or water quality standards, as shown in Figure 2, with the exception of in mid-July, when the SWP pumped an extra 500 cfs for the Environmental Water Account. For the most part Central Valley Project pumping was stable, except at the end of July, when it was reduced to meet Jersey Point water quality, and in mid-September for maintenance.

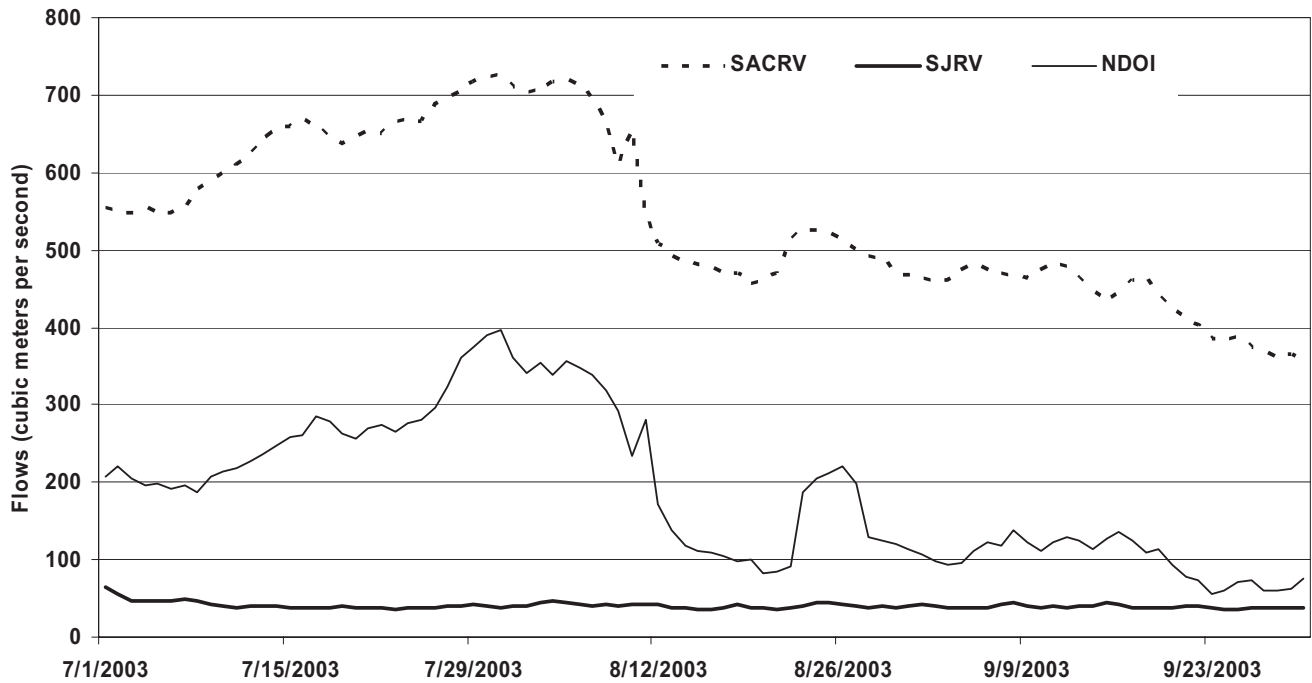


Figure 1 Sacramento River, San Joaquin River, and Net Delta Outflow Index, July through September 2003

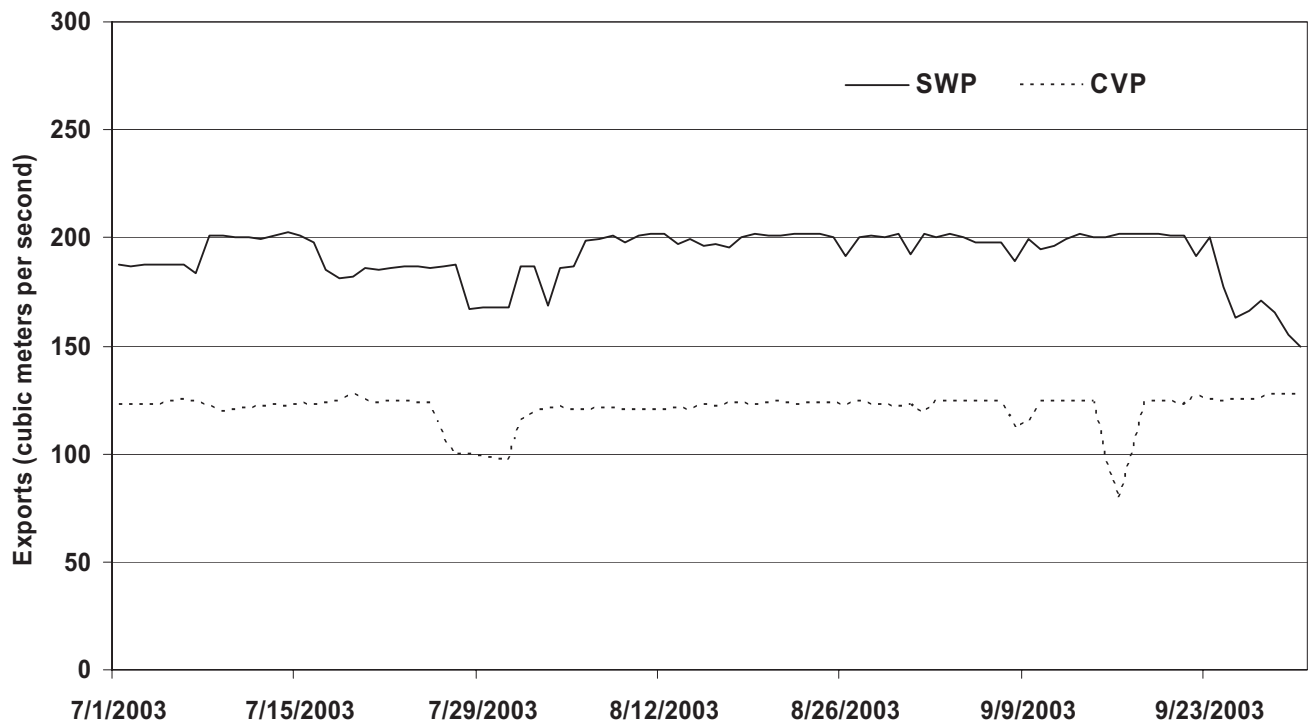


Figure 2 State Water Project and Central Valley Project Pumping, July through September 2003

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■ Interagency Ecological Program for the San Francisco Estuary ■

## ***IEP NEWSLETTER***

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State Water Resources Control Board  
U.S. Bureau of Reclamation  
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